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BRICKWORK
TERRA-COTTA, FAIENCE, AND TILING
BUILDING STONES
MASONRY
CARPENTRY
ROOFING

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MASONRY—*Continued*

CARPENTRY

BRICKWORK

(PART 1)

BRICKS AND BRICKMAKING

MANUFACTURE OF BRICKS

BRICK EARTHS OR CLAYS

1. Constituents of Brick Earths.—Bricks may be called artificial stone, manufactured in small pieces for convenience in laying. The principal ingredients used in manufacturing common or building bricks are alumina and silica, which are the chief ingredients of clay or brick earths. Other substances that form part of ordinary clay, and which either do no good to, or are absolutely harmful to, brick earths when used for the purpose of brickmaking, are lime, iron, salt, etc. Sand, or silica, is found to a greater or less degree in all clays, but should not exist in any excessive quantity, as an excess of sand renders the brick too brittle and destroys cohesion.

Lime in a very finely ground state is necessary in brick earths, as in burning it acts as a flux and causes the grains of sand to melt and help to bind the brick together ; but an excess of lime, or its presence in lumps, is very detrimental indeed to the brick earth. Oxide of iron in the brick earth causes the red colour in the brick after burning, the colour varying with the proportion of iron. The iron also makes the alumina and silica fusible if they are present in correct proportions.

Salt should not be present in the brick earth, except in very small quantities, because it is a strong flux and tends to cause the fusion of the alumina and silica on the outside of the bricks before the heat can burn them throughout.

A good brick earth should have in its composition sufficient flux to fuse its constituents together when burnt, but not sufficient to cause them to run together or become vitrified.

2. **Classification of Brick Earths.**—Brick earths are usually divided into the following groups or classes :

1. *Plastic, or Strong Clays, Known as Pure Clays.*—These clays do not make good bricks, as they have only a small proportion of lime or other similar material present in them to act as a flux to blend the alumina and silica together when heated.

2. *Sandy, Mild, or Loamy Clays.*—The clays in this class are too *loose,* unless a flux is added to unite the particles of silica. In most cases, also, they require washing to free them from stones.

3. *Marls or Limy Clays.*—Clays of this class contain all the ingredients necessary to make good bricks. They contain more lime than the two classes first mentioned.

4. *Malm.*—This substance is an artificial brick earth made by mixing washed clay with the proper proportion of chalk.

5. *Fireclay.*—This earth is a refractory clay, capable of standing great heat without becoming soft.

3. **Colour of Bricks.**—The colour of bricks is governed by several conditions, chief among which are the composition of the clay, the kind of sand used for moulding, the temperature at which the bricks are burnt, the amount of iron present in the clay, etc. Briefly stated, however, **red bricks** are the result of a certain proportion of iron in the clay and a certain temperature while the burning is taking place. **Blue bricks** are obtained by using a clay containing a greater percentage of iron than is used for red bricks, and by the application of a greater heat while burning. The great heat converts the red oxide into black oxide, which combines with the silica and fuses, leaving the brick a dark-blue colour. **White bricks** are produced by the addition of a certain proportion of chalk to the brick earth.

The presence of a small amount of lime and iron is necessary to produce **cream bricks**, while **yellow bricks** are the result of the presence of magnesia and iron in the clay.

PROCESSES OF MANUFACTURING BRICKS

4. **Classification of Bricks, According to Process of Manufacture.**—According to the process of manufacture, bricks are divided into two general classes or groups, as follows: (1) *Hand-made bricks,* which class includes the *slop-moulded* and the *sand-moulded bricks.* (2) *Machine-made bricks,* under which class are included the *plastic* and the *dry bricks.*

5. **Hand-Made Bricks.**—When making bricks by hand the earth of which they are to be made is dug on the premises in the autumn, and this earth, together with any ingredients that are to be mixed with it, is left in rough heaps, to be mellowed by the winter's frost, for as bricks are usually made in the open air, it is not until April that the weather will permit of manufacture. Early in the spring the heaps are dug over and mixed by a man called a *temperer,* who afterwards wheels the clay to a pug mill. A **pug mill** is a machine consisting of a large box or pan in which revolves a central shaft, to which are attached knives or harrows fixed at such an angle that, as the shaft revolves, they cut the brick earth to pieces and thoroughly disintegrate and mix it.

6. It is taken from the mill by a boy who throws it roughly into heaps near the moulders' tables. The mould used is made either of wood lined with brass or iron, or of iron itself. It stands either direct upon the moulder's table, or upon a stock board or projecting piece on the table made to fit the mould. This stock board has usually a projection upon it which forms the indentation found on one side of a hand-made brick, called a *frog.* The moulder takes the mould, wets it, or dips it into the moulding sand which is at the side of his table, and replaces it on the stock, which is also wetted or sanded. Whether the mould and stock are dipped into water or into sand to prevent the clay sticking to them determines the class of the brick turned

out. Thus, a **slop-moulded brick** is one turned out by the wetting process, and a **sand-moulded brick** results from the sanding process. Bricks from the latter process are considered to be sharper and cleaner than those produced by the slop-moulding process.

7. After wetting or sanding the mould, the moulder takes a quantity of brick earth, rolls it roughly into shape and throws it forcibly into the mould, roughly removing the surplus brick earth with his hand. He then takes a flat piece of wood, measuring about 11 inches by 2 inches by $\frac{1}{2}$ inch, called a *strike*, which is kept wet in a small tub of water in front of him. With this he strikes off the superfluous clay, leaving the face smooth. Lifting the mould with the brick in it, he places a *pallet board* beneath it. A pallet board is a piece of board longer than the mould, but of the same width and about $\frac{3}{8}$ inch thick. The moulder then puts mould, brick, and pallet board on a peculiarly shaped barrow called an *off-bearing barrow*, which is large enough to take thirty bricks, skilfully lifts the mould off, and leaves the brick and pallet board on the barrow and proceeds to make another brick. When he has filled his barrow, he wheels it to the *hack*, or long row of boards made to take two bricks sidewise and of any length required. Here they are piled up, not more than eight courses deep, and left to dry, protected from the weather by only light coverings of straw, tiles, or boards called *hack caps*.

8. During this drying process the clay shrinks gradually owing to the evaporation of moisture, and the possibility of cracking is thus reduced to a minimum. After remaining in the hacks for a week or two, depending on local conditions, the bricks are stacked in clamps or kilns and fired, or burnt.

9. Machine-Made Bricks.—Bricks are manufactured by one or the other of two processes, either (*a*) the *plastic-clay process*, which includes the *soft-clay process* and the *stiff-clay process*, or (*b*) the *dry-clay process*.

10. Soft-Clay Process.—In the **soft-clay process** the clay is thrown into a plank-lined pit, where it is soaked in water for 24 hours. The usual custom is to provide several pits, so that

one pit may always contain clay that has been softened by the water and is ready for use, while the other pits are being filled or the clay is in the process of softening. In some localities where the clay is somewhat wet in the clay bank, or where a lower grade of brick is being made, the clay is not wetted until it is placed in the machine.

From the softening pit the clay is taken by a conveyer and dropped into a hopper; from the bottom of which it goes into one end of a trough. Down the axis of this trough runs a revolving shaft with knife blades along its length, that are set at the same angle as the blades of a ship propeller. This shaft with its blades is known, in the machine trade, as a *screw conveyer*, or a *worm*. This worm works the clay to the end of the trough farthest from the hopper. If the clay has not been soaked in the softening pits, it is wetted in the trough by means of a spray, which spreads the water evenly and thus prevents unequal wetting. The blades of the worm help to completely mix the clay and make it homogeneous. At the end of the trough is a plunger that works up and down and forces the clay into a wooden mould, which is divided into six compartments, each one being the size of a brick. The mould is taken out of the machine at each stroke of the plunger and a new one inserted, the bricks being emptied out of the mould on to a board and then taken to the drying yard, where they are allowed to dry before being burnt.

11. Stiff-Clay Process.—In the second and more usual of the plastic processes, the clay, after having been prepared in one of the ways already described, and pugged, is pressed into a machine having a die the exact size of the brick required. The opening in this die is made the size of either the end or the side of a brick. The machine forces a continuous bar of clay through this die, and as it emerges it is automatically cut by wires into bricks, which are then taken to the drying yard, placed in rows, covered by a rough shed, with open sides, and sun or air dried for 3 or 4 days.

12. Dry-Clay Process.—The process often employed in the best work is the **dry-clay process.** In this method of manufacturing

bricks, the clay is used just as it comes from the bank, and is apparently perfectly dry. It contains, however, about from 7 to 10 per cent. of moisture. If it has too much moisture, this is got rid of by treating the clay on a drying floor. It is then put into a form of pug mill in which the pan revolves, carrying the clay under rollers. The bottom of the pan is perforated, to allow the clay when sufficiently ground to fall through in the form of coarse dust into a receptacle beneath. It is then carried by means of elevators to either a circular perforated drum, which is revolving on an inclined axis, or a screen of vibrating piano wires. The fine material passes through, and any which travels to the other end of the cylinder or screen is returned to the pan for further grinding to reduce it to powder. The powder passing through the screen falls into a hopper, where it is treated with sufficient water to make it adhere slightly. It is mixed and forced down with propeller blades, and automatically filled into moulds, of which there are sixteen on a circular revolving steel table. The clay is then automatically forced out of these moulds, and moves on a travelling belt to a press. The moulds in this press are of the same width and length as the brick, but are deeper than the required thickness. A plunger that exactly fits the mould is forced in under heavy pressure and compresses the clay to the size of the brick desired. The bricks are then removed to the kiln and fired.

This method of making bricks is more usually adopted on account of the speed at which they can be turned out, the bricks being of a good shape, compact, and useful for the best work.

13. *Moulded bricks* are made in a similar way, the difference being that the box is made to give the shape of the brick required, and the pressing is usually done by a hand machine.

BRICK BURNING

14. After the bricks have been thoroughly dried, they are usually burnt in *clamps*, or *kilns*, to expel all moisture and to convert them into homogeneous masses by the action of the heat on the fluxes contained in them.

15. Clamp Burning.—In country places, or where only a limited number of bricks are to be made, clamps are used for burning bricks. To ensure dryness, the site chosen for the clamp should be drained before the floor is laid. The floor consists of well-burnt bricks and is honeycombed with flues leading from *eye holes* on the outside.

16. Firewood is placed in the flues and layers of the dry bricks are stacked over them diagonally and about 2 inches apart, the spaces being lightly filled in with coke breeze, and the outside layers, or walls, of the clamp being formed with burnt bricks laid close together. These layers of bricks and breeze, the latter in diminishing thicknesses, are repeated until the desired height for the clamp is reached. The whole is then covered with a few courses of burnt bricks, after which the firewood at the *eyes* is lighted. The fire gradually spreads along the flues and between the bricks, thoroughly burning them in its progress. It often takes four or five weeks for the fire to burn out, the length of time depending on the situation of the clamp and the force of wind it is exposed to. The peculiarity of this process is that each brick contains in itself the necessary fuel for its vitrification, the breeze laid between the bricks when forming the clamp serving merely to ignite the lower tiers.

17. Kiln Burning.—There are many kinds of kilns used for burning bricks, but, generally speaking, a kiln is a rough building, rectangular or circular, consisting of walls without a roof. It has one or more large openings in its walls for access, and also small eye holes, or flue openings, all round the bottom of the walls, near the ground, as receptacles for fuel. The dried bricks are so placed in the kiln as to form flues connected to the eye holes.

When the kiln has been filled, the large openings are closed in with burnt bricks and clay, and fires are started in the eye holes. These fires are kept burning very slowly for a day or two, so that the bricks may become hot all through, after which the fires are increased in intensity until a great heat is obtained. Then the flue eyes are stopped up with brick and clay and the kiln is allowed to cool down gradually.

Bricks from a kiln are generally more uniform in texture and colour than those obtained from a clamp, and are more evenly burnt.

GLAZED BRICKS

18. Use of Glazed Bricks.—The use of glazed bricks has increased enormously in the course of the past few years. They are used greatly for the purpose of reflecting light, and for lining water-closet and bathroom walls, the dadoes of halls and staircases, and in many cases for the entire wall surfaces of dairies, restaurants, hospitals, public waiting rooms, and markets, or wherever a non-absorbent surface that is clean and light is desired.

Glazed bricks can be used for the exterior of buildings as well as for the interior, as they will withstand the most severe changes of weather, and are impervious to moisture when properly laid.

19. Classification of Glazed Bricks.—There are three general classes of glazed bricks known to manufacturers; namely, *salt-glazed bricks*, *half-glazed bricks*, and *majolica-glazed bricks*.

20. Salt-Glazed Bricks.—Salt-glazed bricks are made by throwing common salt into the kiln when the firing of the bricks is nearly completed. The sodium in the salt unites with the silica in the brick clay and forms a glaze on the surface of the bricks.

21. Half-Glazed and Majolica-Glazed Bricks.—The process of manufacture, up to a certain point, is the same for **half-glazed** and for **majolica-glazed bricks**. The bricks may be moulded in plastic clay or pressed direct from clay dust. After they are moulded and pressed, there are two general methods adopted: Some manufacturers apply the necessary bodies and glaze soon after the brick is pressed, and fire it in one process; others take the pressed brick and burn it what is called *biscuit*, or, in other words, burn it at a low heat. Then the bodies and glaze are applied, and the brick is again burnt to flux the glaze. It is important to note that all glazes used in the manufacture of glazed bricks are absolutely leadless except in the case of

majolica-glazed bricks, which require a proportion of this material. In half-glazed bricks the usual colours obtained are white, ivory white, cream, buff, brown, blue, green, and a few others.

22. The chief distinction between majolica-glazed bricks and half-glazed bricks is that the process of manufacture necessitates that the majolica-glazed brick must be twice burnt. After the first burning, a specially prepared soft glaze is applied to the face to be glazed, and the brick is again burnt, this time at a comparatively low temperature. In majolica-glazed bricks a considerably greater number of colours can be obtained than in half-glazed bricks, and a greater variety of shades in each colour.

VARIETIES OF BRICKS

23. Varieties of Common Bricks.—The term **common bricks** includes all those that are intended for structural, not ornamental, purposes, and that require no special pains to be taken in their manufacture. The following is a list of varieties of bricks generally in use for building purposes, but many others might be added to it with special descriptions of types to be obtained from certain brickfields only.

Stocks, or **stock bricks,** are hard, sound, and fairly uniform in colour. They are used for the bulk of ordinary good brickwork, and, when selected, are also used for facing work. They are clamp-burnt bricks and derive their name from the fact that they form the great proportion, or *stock,* of the contents of a clamp.

Flettons, sometimes called **dust bricks,** are made by the dry-clay process, near Peterborough, Northamptonshire, England. They are compact, of good form, and are useful for backings to facing work and for internal walls generally.

Malm builders are kiln-burnt bricks made from specially prepared earth, and are useful for facings.

Red builders are a superior quality of sand-faced bricks, generally used as *rubbers,* a term applied to bricks soft enough to be rubbed to the shape desired.

White Suffolks are of a cream colour and should be used for facing work only, as they are suitable for use as rubbers.

Gault bricks are made from a special clay found in the South-East of England and other places. They are generally white, very hard and durable, and difficult to cut.

Malm cutters are of a light-yellow colour very similar to light-coloured stock bricks, but are more suitable than the latter for use in a good class of facing work.

Some rubbers and cutters are made from a peculiar earth found at Bracknell, Berkshire, and in certain other districts. They are used chiefly for rubbed and gauged work where a good finish is required.

Fareham reds, as their name implies are made from a special earth found near Fareham, Hampshire, England, and are useful for facing work of any description.

Leicestershire reds are a pressed facing brick.

Staffordshire blues are of a deep-blue colour, are very compact, and are suitable for all situations where great strength is required. They are used to a great extent for engineering works, in piers and foundations, and, in fact, in any position where heavy loads have to be carried.

Dutch, or **adamantine, clinkers** are hard, well-burnt bricks often used for pavings. They are generally smaller than ordinary building bricks.

Ganister bricks are considered superior to firebricks in many situations where great heat is to be employed.

Cutters, or **rubbers,** are made from specially washed earth mixed with sufficient sand. When burnt, they are soft enough to be cut or divided with a bricklayer's saw or trowel and rubbed, as their name implies, to a smooth face of any shape desired.

Place bricks are underburnt and very liable to breakage. They are often used to fill in between the framings of wooden partitions to deaden sound. When the partitions are finished in this way, they are said to be *brick-nogged.*

Shippers are bricks that are well burnt and hard, but not of good shape. They derive their name from the fact that many ships take them as ballast.

Grizzle bricks are bricks that are much underburnt.

Burrs are masses of vitrified bricks taken from near the flues of a clamp. These lumps form very artistic rough walling or artificial rockwork.

Chuffs are bricks upon which rain has fallen during the burning process, causing them to crack and rendering them useless for building purposes.

24. Pressed Bricks.—**Pressed bricks** are made by the dry-clay process, or else by placing ordinary moulded bricks, when nearly dry, into a metal mould and subjecting them to great pressure by means of a ram or piston that just fits the mould. Pressed bricks are sometimes dressed or beaten with a piece of wood shaped like a small cricket bat. This serves to consolidate the clay. Bricks subjected to this process are called **dressed bricks.**

25. Purpose-Made Bricks.—Bricks specially made for the particular work in which they are to be used are called **purpose-made bricks.** Moulded and ornamental bricks are now manufactured in a great variety of forms and patterns, so that cornices and mouldings may be constructed entirely of them. If an architect requires special patterns of moulded bricks to carry out designs, most of the larger companies manufacturing bricks will make the special shapes desired if drawings are furnished. The drawings should be drawn to a large scale, and full-sized details should be given.

26. Special Bricks.—There are on the market **special bricks** made in different forms to suit varying situations, such as *arch bricks, moulded bricks, cant bricks,* etc., a number of which will now be described.

Fig. 1

Bull-nosed bricks are shown in Fig. 1, *a* and *b*, and can be used for rounding-off sharp corners.

Coping bricks are made in many different sections and of varying sizes to fit walls of different thicknesses. In Fig. 2 is shown one type.

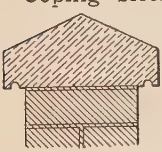


Fig. 2

Moulded bricks are made in different shapes and sizes, and can be used as desired for plinths, cornices, and sills of windows, etc.

Arch bricks, or voussoirs, for circular or segmental arches over door and window openings in brickwork, should be made in the form of a truncated wedge, that is, a wedge with the sharp end cut off. The walls of circular towers, bay windows, etc., are faced with the so-called **circle bricks,** or brick moulded to the curve of the circle desired. The radius of the bay or the tower should always be given when ordering such bricks.

Cant bricks have a bevel taken off one side, as in Fig. 3, *a*. If they are made as shown in Fig. 3, *b*, they are called double-cant bricks.

Fig. 3

Air bricks are used for ventilating purposes when it is desired to allow for a passage of air through a brick wall. They are made of many designs, but the one shown in Fig. 4 is a typical one.

Fig. 4

Fixing bricks are made either of coke breeze concrete, or wood. The former is preferable, as it does not shrink or rot. The bricks are made of a similar size to ordinary bricks and are built into the wall in a similar way for the purpose of affording a fixing for joinery and other materials that have to be kept in place by means of nails or screws. Breeze bricks are usually made by mixing 4 parts of well-burnt breeze with 1 part of Portland cement.

27. Paving Bricks.—**Paving bricks** are usually made by the plastic process, being repressed to give them better shape, and are composed of about 3 parts of shale clay to 1 part of fireclay. They are burnt at a high temperature to the point of vitrification, that is, to a heat at which they begin to fuse. These bricks have a high crushing strength and absorb very little moisture. They are used principally for paving carriageways, and footpaths.

28. Sand, or Sand-Lime, Bricks.—The composition of **sand bricks** is usually 95 per cent. of sand and 5 per cent. of slaked lime.

This mixture is forced into moulds under a very high pressure, and the bricks are then heated with superheated steam. These bricks can be made in many colours by artificial means, and can thus be used to effect the most pronounced designs. Sand bricks are now manufactured by many firms, some of which make a very good dense brick, while others make an inferior sandy article. The best qualities contain a proportion of asbestos, which increases their strength and improves them as non-conductors of heat, cold, and sound; it also improves their weather resisting qualities. One marked advantage in favour of the manufacture of sand bricks is that they do not have to be burnt in a kiln, and are therefore economical to make in a district where fuel is scarce.

SIZES AND WEIGHTS OF BRICKS

29. **Standard Size for Bricks.**—The Royal Institute of British Architects, in conjunction with the Brickmakers' Association and representatives of the Institution of Civil Engineers, have adopted a standard size for bricks and brickwork, which is as follows:

1. The length of the brick should be double the width plus the thickness of one vertical joint.

2. Brickwork should measure four courses of bricks and four joints to a foot.

Joints should be $\frac{1}{4}$ inch thick, and an extra $\frac{1}{16}$, making $\frac{5}{16}$ for the bed joints to cover irregularities in the bricks. This gives a standard length of $9\frac{1}{4}$ inches, centre to centre of joints.

The bricks, laid dry, are to be measured in the following manner:

(*a*) Eight stretchers laid square end and splay end in contact in a straight line to measure 72 inches.

(*b*) Eight headers laid side to side, frog upwards, in a straight line to measure 35 inches.

(*c*) Eight bricks, the first brick frog downwards and then alternately frog to frog and back to back, to measure $21\frac{1}{2}$ inches.

A margin of 1 inch less will be allowed as to (*a*) and $\frac{1}{2}$ inch less as to (*b*) and (*c*).

This is to apply to all classes of walling bricks, both machine-made and hand-made.

The Royal Institute of British Architects' standard has not yet been generally adopted in the British Isles. In many places the sizes of the bricks made average 9 inches by $4\frac{1}{2}$ inches by 3 inches. In the United States the sizes of bricks vary from $7\frac{3}{4}$ inches by $3\frac{3}{4}$ inches by $2\frac{1}{4}$ inches to 9 inches by $4\frac{1}{2}$ inches by 3 inches.

30. Weight of Bricks.—The weight of bricks varies considerably with the material used in their manufacture and also with their size. A pressed brick will naturally weigh more than an ordinary stock from the same yard. The weight of a brick may be anything between 5 pounds and 10 pounds. Roughly speaking, the weight of ordinary stocks are between 6 pounds and 7 pounds; pressed bricks, 7 pounds to 8 pounds; blue Staffordshire, 8 pounds to 9 pounds; and rubbers, over 9 pounds.

STRENGTH OF BRICKS AND BRICKWORK

31. The strength of bricks varies very considerably with the different varieties, some being suitable for positions where they will not have to bear any great load, and others, capable of

TABLE I

CRUSHING LOADS OF BRICKS AND BRICK PIERS IN TONS PER SQUARE FOOT

	Stocks	Gaults	Leicestershire Red	Staffordshire Blue
Bricks	84·27	182·20	362·10	701·10
Brickwork in lime, set 3 to 4 months . .	14·34	21·92	30·74	74·30
Brickwork in cement, set 3 to 4 months .	14·93	33·68	67·76	87·94

bearing great weight, being suitable for foundation and engineering work. The Royal Institute of British Architects recently made exhaustive tests of bricks and brickwork. The results of some of these are given in Table I, where four distinct varieties of bricks are considered. The crushing strength of each is given,

together with the crushing strength of piers built of the several varieties both in lime and cement.

32. As a rule, the brickwork in walls is of ample strength to carry the loads imposed. The principal loads come on the piers and the arches. Of course, the strength varies considerably, as will be seen by looking at Table I, owing to different conditions that may exist; it is influenced by the strength of the bricks taken separately, the materials and quality of the mortar used in laying the brickwork, the workmanship and bond, and the age of the brickwork. It must not be forgotten that the figures given in Table I are crushing loads, and not the safe loads that the brickwork will carry. To ascertain the safe load that a brick pier will carry, the crushing load should be divided by 7 or 8.

33. Bricks should be of uniform dimensions, free from cracks, pebbles, or pieces of lime, and should have sharp corners. They should be well burnt, but not vitrified so that they become brittle. When two good bricks are struck together, they should emit a metallic ring. A good brick will not absorb over 10 per cent. of its weight of water if allowed to soak for 24 hours.

BRICKLAYING

SOLID WALLS

TOOLS USED BY BRICKLAYERS

34. List of Tools Used by Bricklayers' Labourers.—In Fig. 5 are shown some of the tools used by bricklayers and their labourers. At (*a*) is shown a **pickaxe** used for breaking up hard ground. A **shovel** for removing the earth after it has been broken up is shown at (*b*). When clay or similar stiff earth is encountered, a **spade, or grafting tool** (*c*), is used. At (*d*) is shown a boning rod for levelling, the use of which is more fully described in *House Drainage*. The labourer's line is shown at (*e*). The labourer uses this line to set out the sides of excavations or

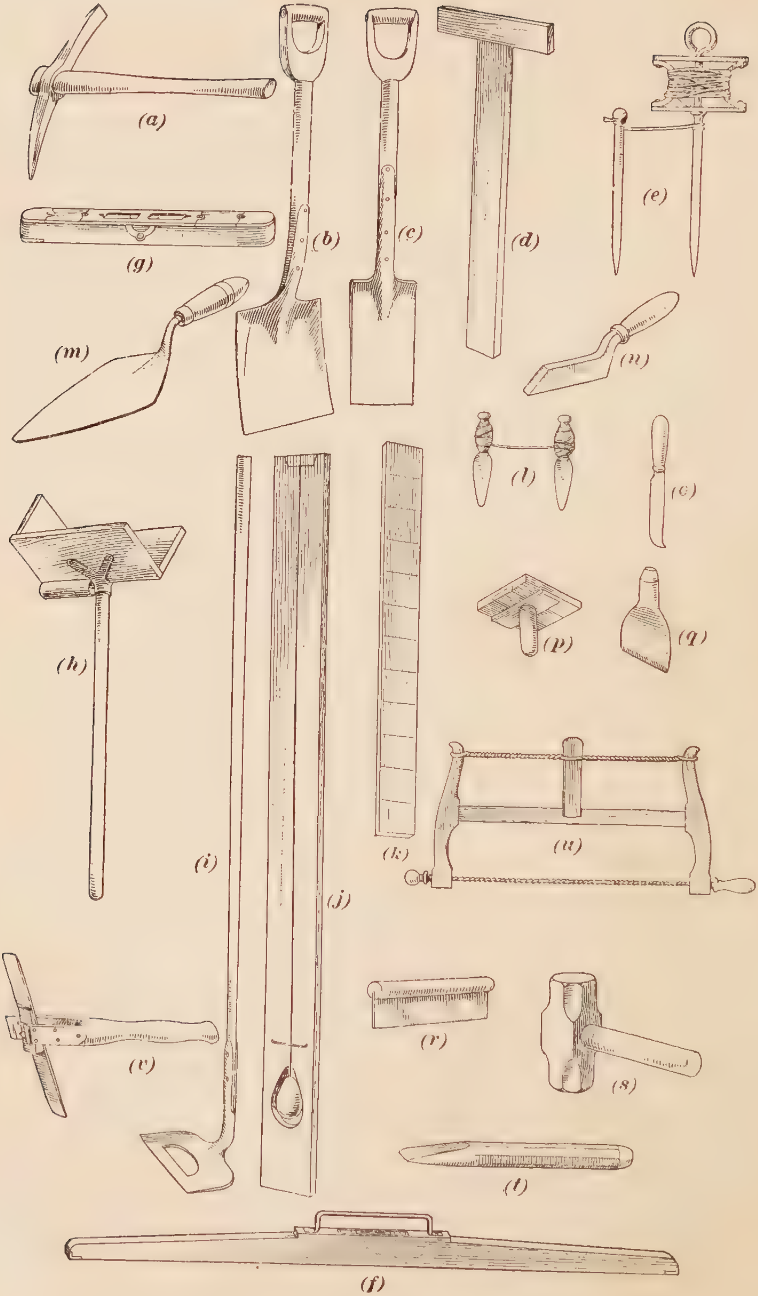


Fig. 5

trenches before he commences digging. He places one peg in the ground at one end of a straight line he wishes to draw, then unrolls the cord and places the other peg at the point to which he wishes the line drawn, pulling the cord tight between the two pegs. (*f*) is the **long spirit level,** and (*g*) the **short, or pocket, spirit level.** At (*h*) is shown the **hod** used by the labourer to take bricks and mortar to the bricklayer. With one arm round the pole, he can rest this hod on his shoulder and at the same time have both hands free to enable him to climb ladders, etc. The mortar is mixed up by means of a long **rake, or larry,** shown at (*i*).

35. List of Tools Used by Bricklayers.—In addition to the tools shown in Fig. 5, the bricklayer uses an ordinary jointed two-foot rule for setting out measurements; a rod, generally 10 feet long, divided into feet and fourth parts of a foot, for setting out longer distances; and a steel measuring tape. The **plumb-rule** shown at (*j*) is used for checking the vertical faces of work and proving that they are absolutely perpendicular. At (*k*) is shown a **straightedge** used for testing the correct setting of bricks to the face of the work. This testing can be done by laying the straightedge against the brickwork and carefully observing that all bricks just touch it. The **line** and **pins** shown at (*l*) are always used by a bricklayer. Before proceeding to lay a new course of bricks, he first lays one or two at a convenient position, preferably the corner of the building, and measures the height of the course to get it correctly. He then drives in one of the pins, proceeds to the other end of the same wall, or any convenient point in its length, and performs the same operation. He then has a straight line stretching between the two pins showing exactly at what height the bricks in the course have to be laid.

The large **trowel** used for spreading the mortar, laying the bricks, and roughly cutting them, is shown at (*m*). A similar but smaller trowel is used for filling the joints with mortar and carefully finishing them, an operation known as *pointing*. The **pointer** (*n*) and **frenchman** (*o*) are also used for pointing brick-work, while at (*p*) is shown a **hawk** used for holding the special mortar when pointing operations are in progress.

Instead of a trowel, a **bolster** (*q*) is sometimes used for cutting bricks. A small incision on the face of the brick is made with the **tin saw** (*r*), then the bolster is applied to this incision and struck sharply with the **club hammer** (*s*). The **cold chisel** shown at (*t*) is used for cutting away or for cutting chases in old brickwork. At (*u*) is shown a **bricklayer's saw** used for cutting bricks when accuracy is required, as for facings. An **axe, or scrutch** (*v*), is used for rough-cutting preparatory to rubbing.

JOINTS IN BRICKWORK

36. Meaning of Brickwork.—By the term *brickwork* is meant not only the bricks, but also the mortar in the joints. It can readily be seen that the strength of brickwork cannot be dependent on the strength of the bricks alone. Other factors influence this, such as the strength of the mortar and the method of laying and bonding the bricks. Therefore, the value of a good brick, so far as strength is concerned, may be decreased by the use of inferior mortar or by being laid by a bricklayer who does not understand his trade.

37. Importance of Mortar.—In laying bricks, it is customary to bed them in mortar. The mortar serves several purposes; it has the effect of making the wall waterproof and air-proof under ordinary conditions. Of course, an ordinary brick wall is never absolutely impervious to water or air; but rain and wind would not get into a house so readily through mortar joints as through a wall built without mortar, or *dry,* as it is called. Another advantage in using mortar in the joints of brickwork is that a wall is made one solid mass, which of course increases its strength and stability. A consideration that is often overlooked, although of importance, is that mortar gives a certain amount of elasticity to the wall. Lime mortar is more elastic than bricks, and thus, by having a light bed of mortar between each course, many bricks are prevented from cracking due to settlement or other causes.

38. Size of Mortar Joints.—In building a wall, sufficient mortar should be used to fill all voids. Since lime mortar,

which is the kind often used in constructing houses, is not so strong as the bricks, it is expedient that little more mortar than just sufficient to fill all voids should be used. Another consideration is that thick joints in brickwork present an unsightly appearance. In laying bricks, a layer of mortar is first spread over the preceding course; then, each brick is laid in place and tapped with a bricklayer's trowel until sufficient mortar is squeezed out to make a joint of the required thickness. If the brick is made with a frog, sometimes called a *kick*, on one side, it is laid with the frog side up. To force a brick down until it touches the brick beneath it is not good practice, as the joints become so thin that they lose much of their strength.

39. Of course, the more regular the surface of the bricks, the closer they can be laid and the smaller will be the joints. With ordinary brickwork, the joints should not average more than $\frac{1}{4}$ inch in thickness. Suppose that the height of eight courses of bricks as laid in a wall were 24 inches, and that each

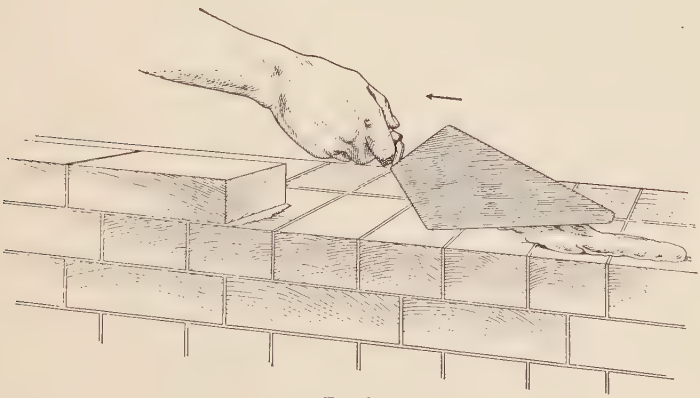


FIG. 6

brick measured $2\frac{3}{4}$ inches in height; then, eight bricks without any mortar should measure 22 inches, and the total thickness of mortar in the eight courses would be $24 - 22 = 2$ inches. Therefore, each joint would average $\frac{1}{4}$ inch, which is the usual maximum allowable average joint in ordinary work. In pressed-brick work, however, the joints can be made smaller, probably $\frac{1}{8}$

to $\frac{3}{16}$ inch being about the usual thickness, because the bricks are smoother and have no irregular projections.

40. Method of Laying Bricks.—In laying bricks, it is customary to lay the two outside courses first. As shown in Fig. 6, a trowel with mortar on it is held over the wall and moved in

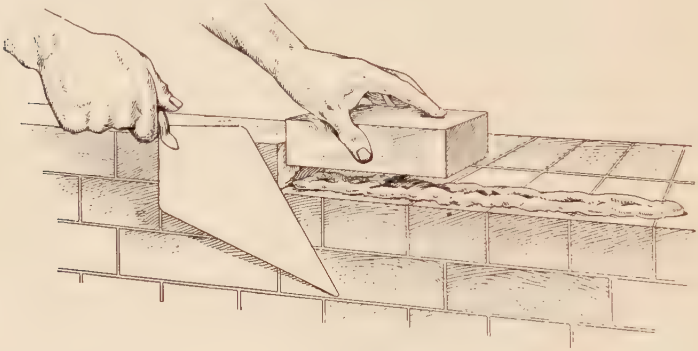


Fig. 7

the direction of the arrow, at the same time being tilted so as to allow the mortar to slide off. This motion has a tendency to distribute the mortar along the wall. The mortar is then

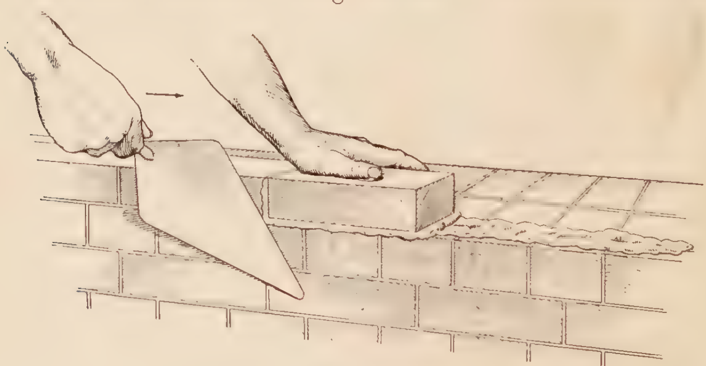


Fig. 8

still further spread with the point of the trowel, which, by a vibrating movement of the hand, causes the mortar to form little ridges. A brick is then placed on the wall and pushed into place, as shown in Fig. 7. This operation has a tendency to squeeze the excess mortar out of the joint between the bricks,

as shown in Fig. 8. The brick is, if necessary, then tapped down with the handle of the trowel, and all the excess of mortar thus squeezed out at the joint is then removed with the trowel, as shown in Fig. 8, by scraping it along in the direction indicated

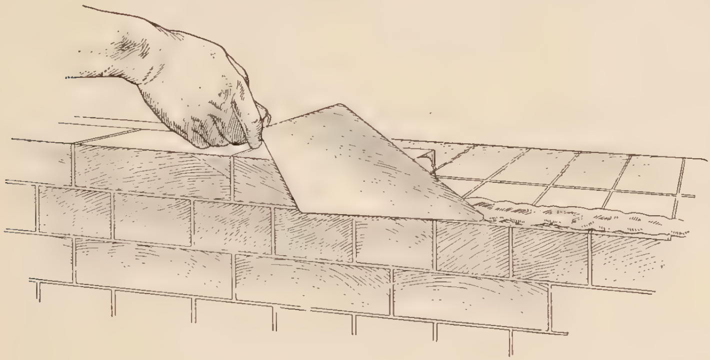


FIG. 9

by the arrow. This extra mortar, which sticks to the trowel, is then scraped off against the edge of the brick to fill the vertical joint between it and the next brick to be laid, as shown in Fig. 9.

41. After the two outside courses have been laid, the middle courses are put in; all the *bats*, or broken bricks, are used here, as they will not be seen. In first-class work, however, no bats are permitted, except where absolutely necessary to get the correct bond, as their introduction increases the number of mortar joints. A mortar bed is laid the same as for the outside courses, and the bricks are slid and tapped down into it. The vertical joints are usually filled by picking up a little mortar on the trowel and forcefully throwing it down on the joint. This, however, is not good workmanship, and, if the bricks are properly laid, cannot be done as the joints are too close to admit of it. The vertical sides of each brick in position should be thinly coated with mortar, with the trowel, before the next brick is placed in position.

42. Laying Pressed Bricks.—Pressed bricks are usually laid in a better quality of mortar than that used for common

brickwork. The sand used in the mortar is usually finer, so that the joints between the bricks can be made thinner, and the mortar is often coloured with mortar stains. In laying enamelled bricks in bathrooms and similar places, the joints are usually kept down to $\frac{1}{8}$ inch. Pressed-brick work is sometimes *striped ;* that is, the joints are painted with a brush guided by a straightedge, the colour of the paint employed being in contrast with the remainder of the work. This is called *ruled work.*

43. Laying Bricks in Severe Weather.—When bricks are dry, they absorb moisture from the mortar in which they are laid and thus prevent the mortar from attaining its customary strength. It is, therefore, very important, especially in warm weather, that all bricks be wetted with water before they are laid in the wall. In freezing weather, it is advisable that the laying of bricks should be entirely discontinued, as the action of frost on mortar is very detrimental to its setting properties.

BOND IN BRICKWORK

44. Necessity of Bonding.—Lime mortar is not so strong as bricks, at least for some time after it has set. It can easily be seen that if each brick in a wall were placed directly on another brick, any great weight imposed might cause the vertical mortar joints to split open. There is something more to be considered in laying bricks than to place each one on a bed of mortar. A brick wall, if built correctly, must be tied together so that as much as possible of the strength of the bricks will be utilized.

45. In bricklaying, all corners and joints should be carefully plumbed, the courses of brickwork kept perfectly horizontal, which necessitates uniform mortar joints, and the wall surfaces, both exterior and interior, must be kept in perfect alinement. All these conditions may have been complied with, and yet the work may be imperfect ; the merit of brickwork must be judged by the thoroughness of the *bond* observed in every portion of the wall, both lengthwise and crosswise. This bond must be maintained by having every course perfectly horizontal, both longitudinally and transversely, as well as perfectly plumb.

Apart from the quality and character of the material, the *bonding* of a wall contributes most to its strength.

46. Terms Used in Bonding.—By **bonding** brickwork is meant the process of laying bricks across one another so that one brick will rest on parts of two or three bricks below it. This amounts to the same thing as breaking the joints. When built in this manner, it is difficult for a wall to fall without breaking the bricks.

When the bricks are placed lengthwise on the face of the wall, as at *a*, Fig. 10, they are termed **stretchers**; when placed

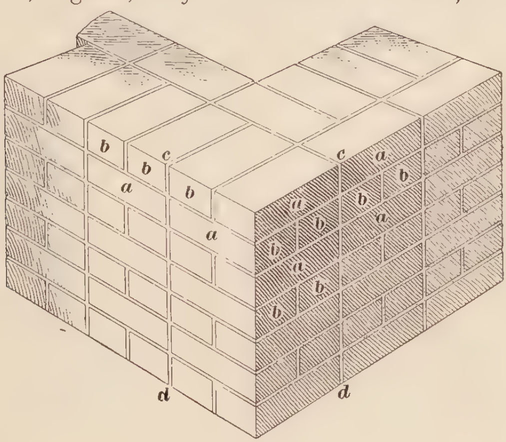


Fig. 10

crosswise and their ends only are exposed to view in the face of the wall, as at *b*, they are called **headers.** A **course** means the thickness of a brick and a mortar joint.

47. Closers and Bats.—The blocks of different sizes used for bonding are called **closers,** the term meaning that they perfectly finish, or close, the length of the courses that have been adjusted to obtain the bond. The vertical joint, which is shown at *c d*, Fig. 10, is avoided, and no two adjacent courses have joints that are immediately over each other. The closers are made by cutting the brick into such blocks as the situation requires, the operation being performed by striking a brick a sharp blow with the edge of a steel trowel. The cut bricks are called **bats,**

and are designated according to the proportion that each bat bears to a whole brick. Pressed and enamelled bricks are often cut with a bolster to get a more even fracture.

48. The different bats or closers used in brickwork are shown in Fig. 11, (*a*) representing a whole brick of the usual size. When a brick is cut longitudinally, as at (*b*), on line *a b*, each half is called a **queen closer**; but as it is difficult to cut the full length in this manner, the usual mode is to first cut the brick on the line *c d e*, and then cut each half on the line *a b*. When the brick is cut as at (*c*), it is called a **king closer**, and is a form well adapted for closers at door and window jambs. When one-fourth of the whole length of the brick is cut off, as at (*d*),

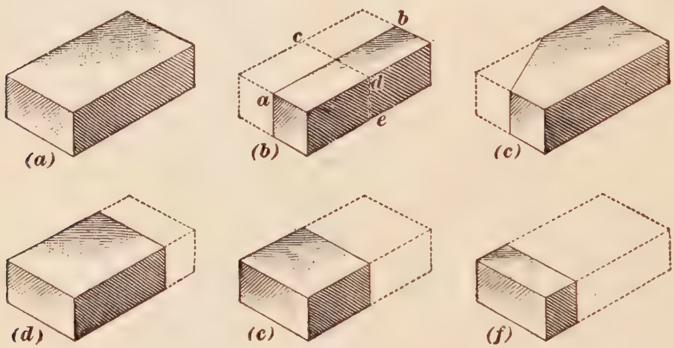


Fig. 11

the remainder is called a **three-quarter bat**; and, in like manner, the portion remaining at (*e*) is called a **half bat**; and at (*f*), a **quarter bat**.

49. In connection with the use of closers, whereby the lap is properly secured, there are several methods of placing the brick in the wall, each method having its own name to indicate the kind of bond used. A wall being considered as having the properties of a column, its bearing capacity will necessarily depend on the strength of its least dimension, which is its thickness, so that the bond that secures a thorough union of the constituent parts in this direction will always be the most desirable.

50. Keeping the Perpends.—To obtain the best results in bonding throughout the mass of the wall, strict attention must be given to the position of every joint in the brickwork. On the faces of the wall, the vertical joints in each course throughout the height should be kept perpendicular, or directly over those in the second course below. This is called **keeping the perpends.** Unless the closest attention is paid, the lap is ultimately lost through irregularity of the brick and mortar joints, and extra bats, or closers, become necessary. The joints across the top of the wall should also be kept in line, so that if the perpends are observed on one face of the wall, the other face will also work up correctly. Even when the wall is exposed on only one face, the importance of having the joints on top of the wall kept in line is just as essential; otherwise, its effective longitudinal bond will soon be lost, since at best the heading bond furnishes a lap of only $2\frac{1}{4}$ inches.

51. Necessity of Preserving Bonding.—The importance of having the bond in brickwork preserved in the whole wall can be understood by referring to Fig. 10, which represents a section of a wall consisting of alternate courses of stretchers and headers. By the method of placing the bricks as shown, no longitudinal bond exists, and the wall is simply a series of contiguous piers that join one another at the vertical lines *c d*, and have no bond or union between them other than that obtained by the adhesion of the mortar. This method manifestly lacks strength and stability. In order, therefore, to overcome this constructive difficulty and to secure a continuous bond in the length of the wall, recourse is had to a different arrangement of the bricks and also to the use of bats.

KINDS OF BOND

52. Heading Bond.—When all the courses present the ends of the bricks on the face of the wall, the wall is then composed entirely of *headers*, and is said to be built in **heading bond.** This method, however, is only adapted for use in sharp-curved walls, as it possesses little longitudinal bond.

53. Stretching Bond.—Stretching bond is the one employed when all the courses consist of *stretchers*. The wall formed by this method should only be used for partitions that are but $4\frac{1}{2}$ inches in thickness; where the wall is thicker than this, the method should not be followed, as there would be no transverse bond.

54. English Bond.—English bond is probably the best and strongest method of bonding brickwork. In this bond, header and stretcher courses are laid alternately, as shown in Fig. 12. Joints are broken in the longitudinal bond courses by the use of quarter-bat closers, marked *c*. This is, without doubt, the best and simplest method to follow in all work where strength is required, as by its use a complete and thorough transverse bond

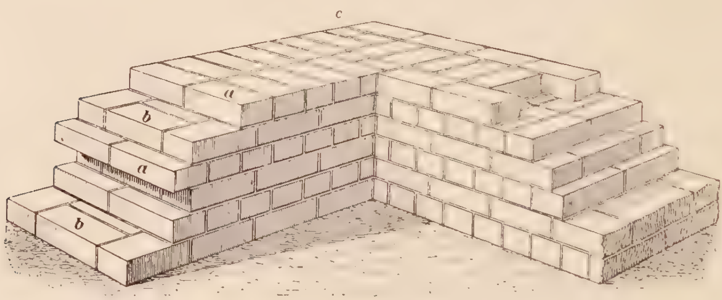


FIG. 12

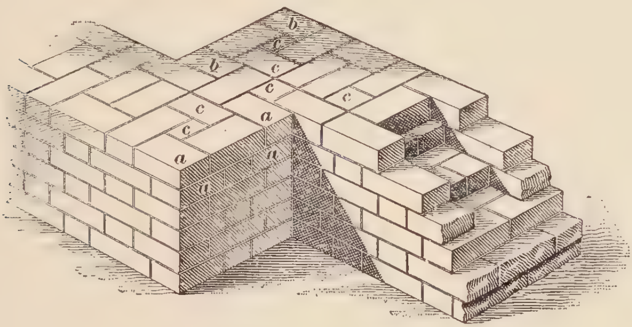
is formed. It will be observed that the heart of the wall consists entirely of heading bond, and that the joints of the heading course, as at *a*, are well bonded by the headers of the stretching course, as at *b*.

Joints can be broken in English bond courses by the use of the three-quarter bats, and many authorities prefer them to quarter-bat closers, as by using three-quarter bats only one mortar joint instead of two shows in the face of the wall.

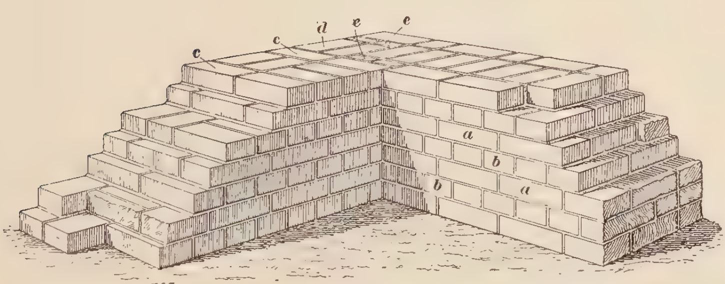
55. An objection frequently urged against the appearance of English bond is the recurrence of so many headers in the face of the wall, which gives the work the appearance of being constructed of so many tile-like blocks. The use of diminutive

blocks of either brick or stone in heavy walls always tends to reduce the apparent strength of the structure, and it loses much of the effect of permanence, which is a very effective factor in good design.

56. Flemish Bond.—The **Flemish bond** is one where only two-thirds of the number of headers that occur in English bond are exposed, and each course is composed of a header and a stretcher alternately. The method of laying bricks in Flemish bond is shown in Fig. 13 (*a*). The lap in this case is obtained



(*a*)



(*b*)

Fig. 13

by the use of three-quarter bats, both at the external and the internal angles of the wall, as shown at *a* on the external and at *b* on the internal angles. In Flemish bond the closers occur in the heart of the wall, just as was shown in English bond; these are quarter, half, and three-quarter bats, as shown at *c*.

It will be seen, by referring to the illustration, that owing to the headers and stretchers being placed on the inner side of the wall immediately opposite those on the outer face, both faces will appear exactly alike when thus arranged. The wall is then said to be built in **double Flemish bond.**

By carefully examining the illustration, it will be found that only one-half of the body of the $4\frac{1}{2}$-inch thickness is bonded to the adjacent thickness; in other words, the upper bed of each face stretcher is bound to the inner thickness by only the width of one header. In this respect, the strength of the wall is sacrificed for the sake of appearance. A continuous vertical strip $2\frac{1}{4}$ inches wide occurs on each side of the face headers, and has no bond other than that of the adhesion of the mortar. To obviate this defect, the outer face is sometimes built in Flemish bond and the inner face in English bond, as shown in Fig. 13 (*b*). At *a* is shown the stretcher course of the English bond on the inner face, while at *b* is shown the header course. At *c* is shown a header, and at *d* a stretcher next to it in the course of Flemish bond facing on the outside face of the wall. The bond in the interior of the wall is obtained by means of bats *e*, *e*.

57. English and Flemish Garden-Wall Bond.—**English garden-wall bond,** Fig. 14, consists of one course of headers to three of stretchers, and **Flemish garden-wall bond,** Fig. 15, is

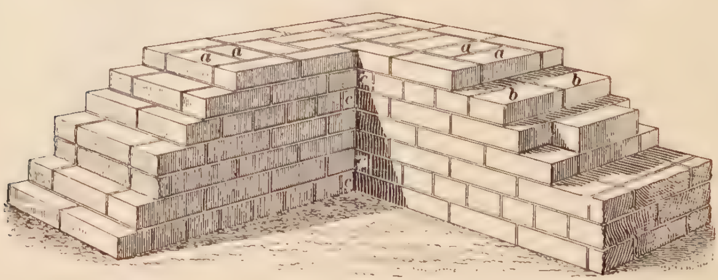


FIG. 14

formed by building one header to every three stretchers in each course. In each case the longitudinal lap is secured by closers *c*; the heading course in the heart of the wall, Fig. 14, is shown

at *a*, being placed immediately over the heading course *b* exposed on the face. It is useful in 9-inch walling where both faces will be exposed, and when difficulty is experienced in getting bricks of such sizes that the length of the brick is equal to twice its width plus one mortar joint.

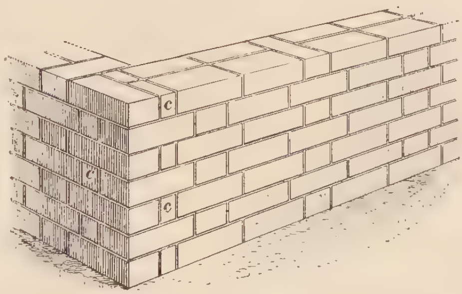


Fig. 15

58. The principal defect of the garden-wall bond is that the wall is practically composed of a series of $4\frac{1}{2}$-inch layers, which have no transverse bond other than the mortar. It fulfils the requirements, however, if every joint throughout the body of the wall is well filled with good mortar and the vertical joints are well rammed with the edge of the trowel.

59. Diagonal Bond.—In Fig. 16 is shown a wall 2 feet $7\frac{1}{2}$ inches in thickness with the face bricks bonded to the common bricks by what is known as **diagonal, or herring-bone, bond.** At *a, a* are shown the front bricks, laid as stretchers on one face of the

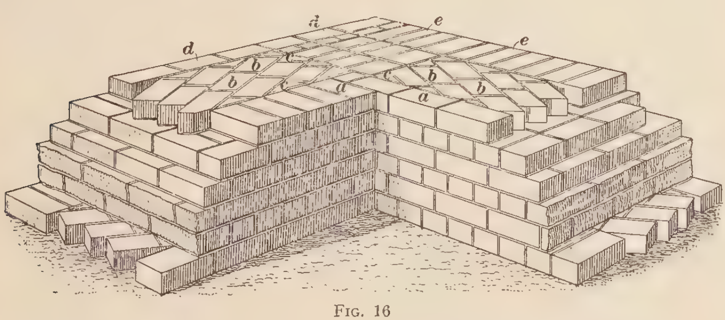


Fig. 16

wall and as headers in the same course on the return face ; at *b, b*, the bonding bricks laid diagonally ; at *c, c*, the different shaped bats laid to form the closers of the bond bricks ; at *d*, the outside course of stretchers ; and at *e* the outside course of headers.

60. Hoop-Iron Bond.—Walls are sometimes strengthened in their bonding by the insertion of hoop iron, which has taken the place of the old method of building longitudinal bond timbers into walls. Long thin strips of wrought iron $1\frac{1}{2}$ inches wide by $\frac{1}{16}$ inch thick, are tarred and sanded and laid as shown at *a, a* in Fig. 17. The ends are joined by being bent so as to hook over each other as at *b, b* both at longitudinal and right-angle joints.

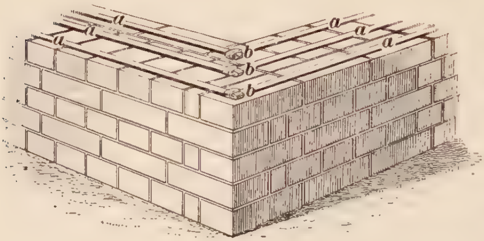


Fig. 17

HOLLOW WALLS

61. Object of Hollow Walls.—Walls are sometimes built in two thicknesses, or shells, with a space between, as shown in Fig. 18. The object of this arrangement is to protect the interior surface of the wall from dampness when the exterior is exposed to severe and prevalent winds and rains. It is claimed that the damp can only penetrate the outer shell, the cavity between the shells forming an effective barrier to its further progress.

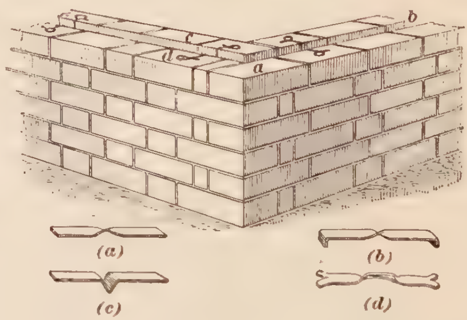


Fig. 18

When building hollow walls some means must be adopted to tie the two shells together, and for this purpose bonding ties or bricks are built in at intervals.

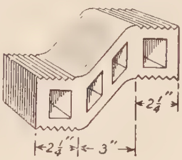
62. Bonding With Metal Ties.—Probably the best method of bonding the two sides of a double, or hollow, wall is by the

use of metal ties, as they will not carry any moisture across, especially when there is a dip or sudden bend in their length.

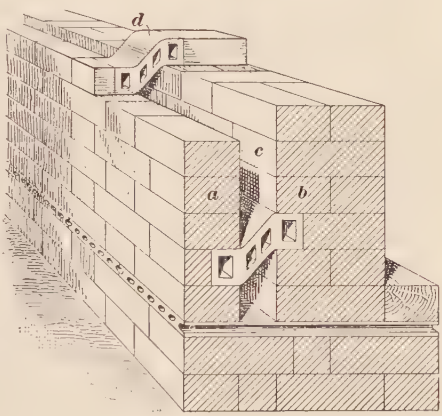
At *a*, Fig. 18, is shown a $4\frac{1}{2}$-inch wall; at *b*, the air space; at *c*, the inner $4\frac{1}{2}$-inch wall; and at *d*, the metal ties. At (*a*), (*b*), (*c*), and (*d*) are shown other forms of ties. The form shown at (*a*) is that most used in the British Isles.

When any of the metal ties (*a*), (*b*), (*c*), or (*d*) are used, they should be spaced every 24 inches in every fourth course. Metal ties should be dipped in hot asphalt before fixing to prevent them from rusting.

63. Bonding With Bonding Bricks.—Patent vitrified or glazed bonding bricks can be obtained and are often used instead of the metal ties shown in Fig. 18. They are shaped as shown in Fig. 19 (*a*); and in Fig. 19 (*b*) is shown the method in which they are built into a hollow wall, *a* being the $4\frac{1}{2}$-inch outer lining, *b* the 9-inch inner lining, *c* the air space between, and *d* the bonding brick.



(*a*)



(*b*)

FIG. 19

64. Bonding With Wire-Netting Strips. There has recently been placed on the market a system of reinforcing brickwork by means of the insertion of wire-netting strips about $2\frac{1}{2}$ inches wide. These are built in every fourth course, or in brick on edge in every other course. It is claimed for the system that a 9-inch hollow wall composed of $4\frac{1}{2}$-inch outer shell, $1\frac{1}{2}$-inch cavity, and 3-inch inner leaf (brick on edge) reinforced by this system is as strong

and effective in damp-proof and fire-resisting qualities as the ordinary $16\frac{1}{2}$-inch hollow wall shown in Fig. 19 (*b*). The material can be used in a hollow wall as a bonding tie if desired.

In the case of buildings the skeletons of which are either of steel construction or reinforced concrete, bonding strips of the wire mesh are secured to the steelwork or inserted in the concrete during construction. After the removal of the moulds, the projecting ends are turned outwards and the reinforced cavity or partition walls bonded thereto.

The system seems admirably adapted for the clothing of such framed buildings, whether of steel or reinforced-concrete construction.

JOINING NEW WALLS TO OLD WALLS

65. In joining a new wall to an old one, the new work should not be toothed, or bonded, into the old work unless the new work is built in cement mortar. All brickwork built with lime mortar will settle somewhat, owing to a slight compression of the mortar joints, and this settlement is liable to cause a crack where old and new work is bonded together. In place of toothing, or bonding, a groove should be cut perpendicularly in the old wall, usually the width of a brick, so as to make a joint; this is called a *slip joint*.

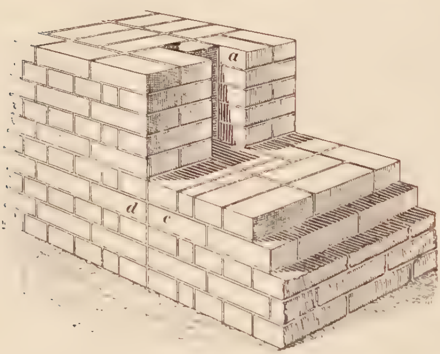


FIG. 20

The method of bonding just described is shown in Fig. 20. At *a* is shown the groove or chase cut, where the new wall is to enter the old wall; *c* is the new wall, and *d* the old wall. In cheap construction, where new work is bonded into old, the method most commonly used is to nail a piece of $4\frac{1}{2}'' \times 2\frac{1}{4}''$

timber against the wall, as shown in Fig. 21, where *a* shows the $4\frac{1}{2}'' \times 2\frac{1}{4}''$ timber spiked to the old wall and entering the centre of the new wall. At *b* is shown the old and at *c* the new wall.

JOINTING BRICKWORK

66. There are two ways of jointing brickwork, *natural* and *artificial*, both having the same object, that of preventing the access of water to the interior of the joint. The natural method is simply called *jointing*, while the artificial method is termed *pointing*.

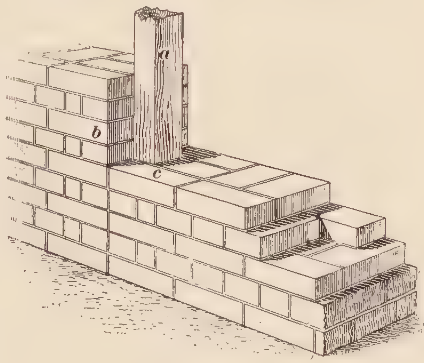


Fig. 21

67. Jointing.—When brick walls are to be furred and plastered or are otherwise protected from exposure, the joints between the bricks are merely smoothed off flush with a trowel. However, if the face of the wall is exposed, the joints are *struck*, as shown in Fig. 22 (*a*), where *a* shows the mortar joint and *b*, *b* the bricks in the wall. In striking a joint like this, the point of the trowel, which is held obliquely, is used. This method makes the better job for outside work, as the water will not lodge in the joint and soak into the mortar, as would be the case if the joint were struck in the manner shown at (*b*). The second form, however, is easier to make.

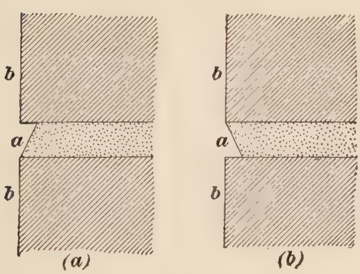


Fig. 22

68. Pointing consists in scraping out the old mortar in the outer joints to the depth of at least $\frac{1}{2}$ inch and then filling them

with specially prepared fresh mortar, generally made with cement, which is well worked in with a trowel.

In many cases, both old and new work need to be repointed after laying. In new work, however, if attention has been paid to laying the bricks properly, with good ruled joints for face bricks and neatly struck joints for common bricks, *pointing up* may not be necessary.

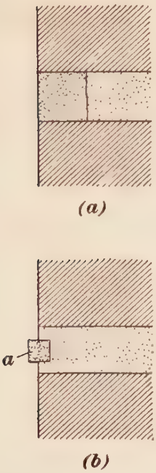


Fig. 23

69. In Fig. 23 are shown two varieties of pointing. **Flush pointing** is shown at (*a*), where the mortar is raked out, as above described, and cement or other fine mortar is applied to make the joint flush with the face of the brickwork. At (*b*) is shown **tuck pointing,** where the mortar joint is made flush and a small groove is raked out in it into which is inserted a tuck or point of cement shown at *a*.

BRICK ARCHES

TERMS USED IN CONNECTION WITH ARCHES

70. When properly built, brick arches form one of the most secure spans for a door or a window, especially if the opening is wide. Arches should be built in cement mortar by careful and experienced workmen, or otherwise there is danger of the arches cracking and letting down the weight imposed on them.

71. Definition of Terms.—In order to obtain a better understanding of this subject, the following definitions of terms used in connection with arches are given. They may be readily understood by referring to Fig. 24.

Span.—The distance between the abutments, as shown at *a b*.

Springers, or Skew Backs.—The stones or bricks that lie immediately on the imposts, as at *c*, *c*.

Springing Line.—A line drawn through the points where the arch intersects the abutments, or where the vertical supports of the arch terminate and the curve begins, as shown at *e d*.

Intrados.—The lower concave surface of the arch, formed by the under sides of the bricks, although considered by some authorities to be the concave line at the edge of the under side of the bricks.

Soffit.—The lower surface of the arch, or the intrados.

Extrados.—The upper convex surface of the arch formed by the outer sides of the bricks in the arch; also considered

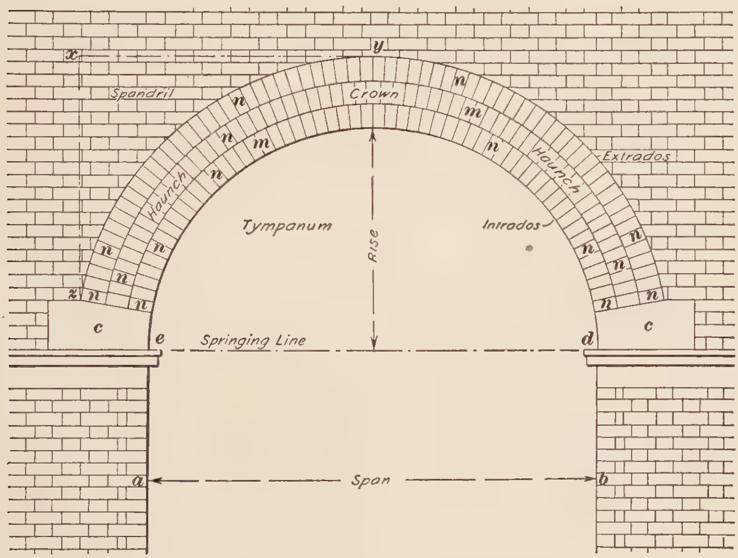


Fig. 24

by some authorities as the convex line of the curve of the outside of the arch.

Rise.—The perpendicular distance from the springing line to the highest point of the intrados.

Crown.—The highest portion of the arch.

Key.—The uppermost and last laid brick or stone in the ring of an arch.

Haunches.—The portion of the arch included between the crown and the skew backs.

Tympanum.—The space between the springing line and the intrados.

Spandril.—The triangular wall space included between the extrados, a horizontal line drawn through the crown of the arch, and a vertical line drawn through the extremities of its extrados. The spandril is shown at *z x y*.

Spandril Filling.—The brickwork filling the spandril.

Arch Ring, or Rowlock.—One of a series of arch courses composed of voussoirs. There is no bond between these rings other than that afforded by the adhesion of the mortar, as shown at *m, m*. Sometimes called a rowlock.

Voussoir. — One of the bricks or stones which help to form each ring of the arch, as shown at *n, n*.

CLASSIFICATION OF ARCHES

72. Brick arches are divided into *rough-brick arches* and *gauged* or *rubbed-brick arches* according to the method of preparation of the bricks or voussoirs used for them.

73. Rough Arches.—When arches are constructed of common bricks, they are called **rough arches.** The bricks are laid close

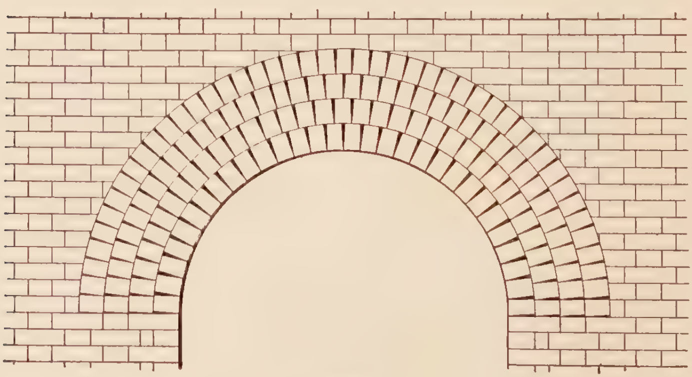


Fig. 25

together on the intrados, with wedge-shaped joints on the extrados; that is to say, the mortar joints are wider at the upper surface of the brick ring than at the lower surface, so

that there is more mortar at the top of the joint than at the bottom. The bed surfaces of the bricks are therefore not on radial lines, as they are in a gauged-brick arch, but the radial lines are assumed to pass through the centre of each mortar joint.

Fig. 25 shows a semicircular arch consisting of four rings of brickwork. These arch bricks are all laid as headers, and show a 9-inch reveal on the soffit of the arch. The increase of the thickness of the mortar in the joints is much exaggerated in the illustration.

74. In arches of large span built of common bricks, especially in the brick lining of tunnels and vaults, the bond is often effected by building in headers, which will unite the concentric rings where the joints of two of the rings come together.

An example of this is given in Fig. 26, which shows an arch of four rings, two being header and two stretcher courses, the header and the stretcher courses being bonded by headers, as shown at *a*, *a*.

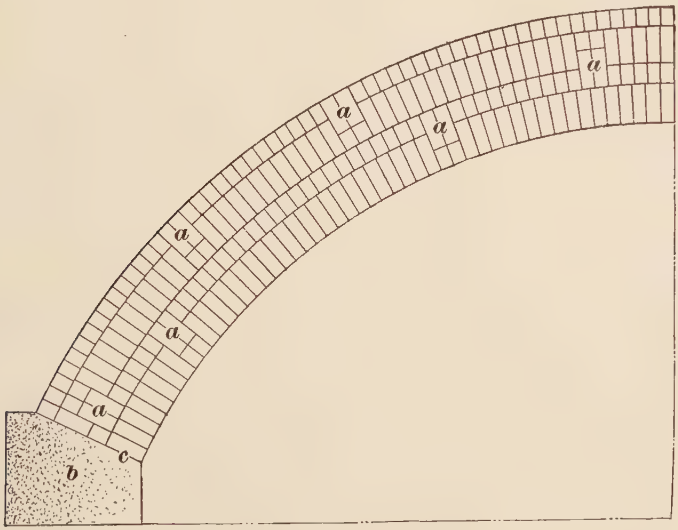


FIG. 26

75. Skew Backs.—When brick arches of large span are to be built, they should in all cases have skew backs or springing

stones, as shown at *b*, Fig. 26. The stone should be cut so as to bond into the brickwork of the pier, and the surface *c* from which the arch springs should be cut to a true radial plane.

76. Gauged or Rubbed-Brick Arches.—When arches are built of common bricks, the mortar joints become wider from the soffit to the extrados. It will be noticed by referring to Figs. 25 and 26 that there are more bricks in the outer rings of the arches than in the inner rings. This is, of course, due to the fact that the circumference of the outer circle is larger than the circumference of the inner circle. If an attempt were made to have continuous radial joints from the inside course to the outside course, in an arch of considerable thickness built up with common bricks, these joints would become very wide indeed at the extrados. For this reason, **gauged bricks** are sometimes employed.

77. The gauging, or shaping, may be accomplished by setting out the arch ring on a floor, and cutting, rubbing, or grinding the bricks to a certain gauge, or pattern, so that each brick will fit exactly in the place chosen for it ; and all the mortar or radial joints will be of the same thickness throughout.

Gauged, or shaped, bricks are supplied by most of the brick manufacturers, who prepare the bricks so that each one will fit accurately in its position in the arch. When these bricks are ordered from the manufacturers, either full-sized or large-scale drawings should be furnished, giving the span of the opening, the radius of the arch, and the depth of the reveal.

It will always be found that rubbed bricks, that is, bricks that are shaped after they are made, will fit better than moulded bricks, or bricks that are first made wedge-shaped and then burnt, because the latter are liable to become warped in burning.

78. Shape of Arches.—An arch is generally known by the shape of the curve of which it is made up ; thus, a **semicircular arch** is shown in Fig. 25. A **stilted arch** is one that has its centre raised above the springing line of the arch, as shown at (*a*), Fig. 27. At (*b*) is shown a **lancet arch.** An **equilateral arch** (*c*) has its centre at the point where the springing line intersects with the line of the opening under the arch. At (*d*) is shown a

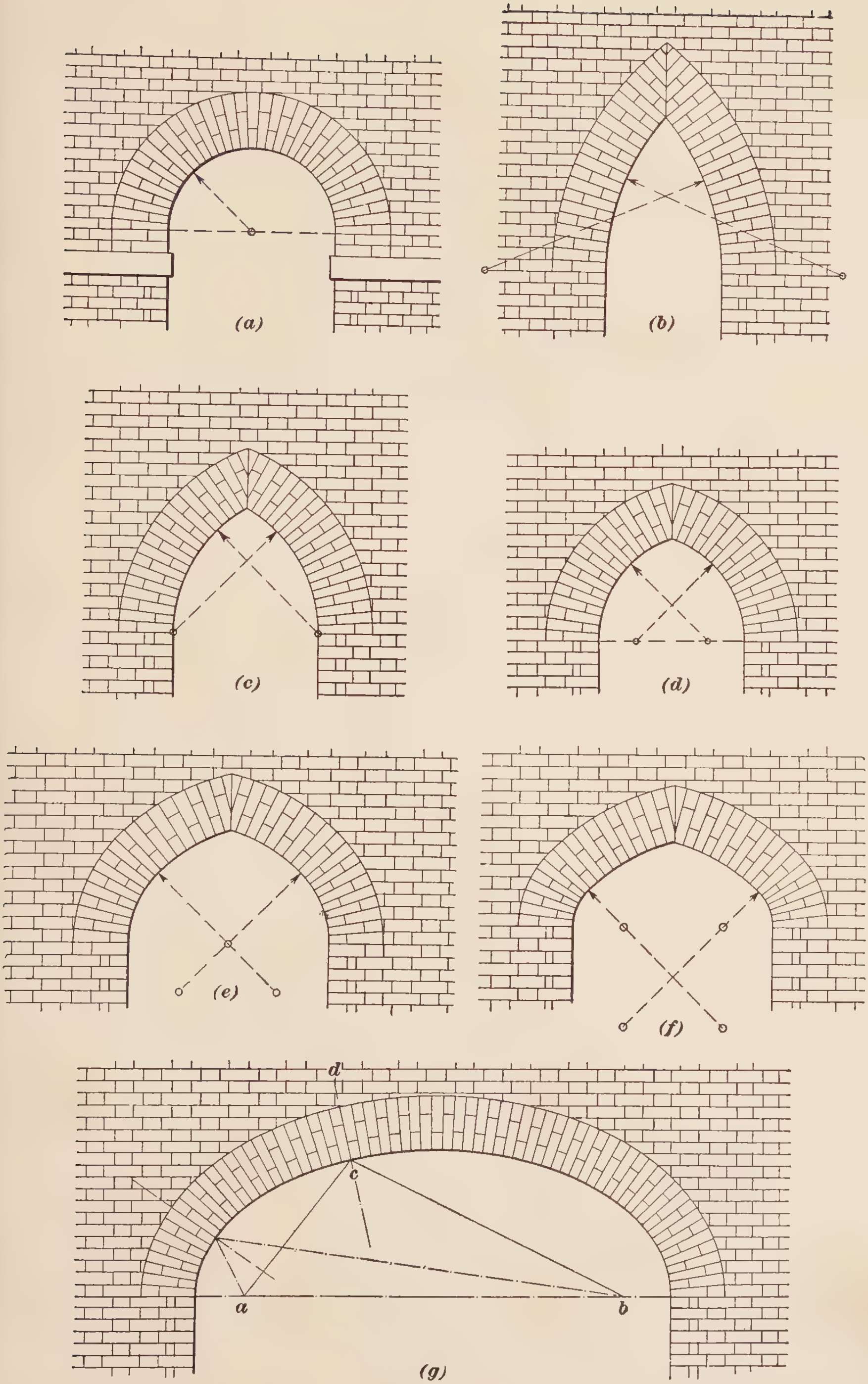


FIG. 27

drop arch, while at (*e*) and (*f*) are shown three and four centred arches respectively. At (*g*) is shown an elliptical arch. It will be found that every voussoir in an elliptical arch is of a different shape from the one immediately next to it, so that each requires a separate template. The method of finding the angle to which each voussoir is to be rubbed is as follows: From *a* and *b* in Fig. 27 (*g*), the eyes, or foci, of the ellipse, draw lines *a c* and *b c* to the points on the circumference of the ellipse of each brick joint. Then bisect the angle *a c b*, when the line *c d* will give the exact angle to which the voussoirs on either side of it have to be rubbed. A similar process can be gone through with every voussoir joint.

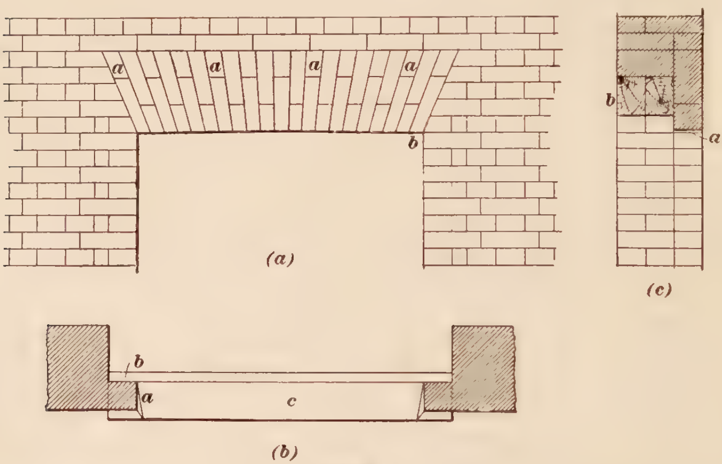


Fig. 28

79. Flat Arches.—Fig. 28 (*a*) shows a **flat arch** that is bonded into the rear wall by headers *a*, *a*. It is best to give the soffit of such arches a slight camber, or curve, say $\frac{1}{8}$ inch rise per foot of span, as shown at *b*, because when they are made level they are almost sure to settle and sag a little and crack the glass in the sash. In the plan of the window opening and sill, Fig. 28 (*b*), *a* shows the reveal of the brickwork; *b*, the $4\frac{1}{2}$-inch offset for the frame of the window; and *c*, the window sill. The section (*c*) shows the under side, or soffit, of the arch at *a* and the wood lintel at *b*. This wooden lintel is placed behind the brick arch.

and may also be used as a support for the floor joists. The lintel may have a bearing of from 4 to 6 inches at each window jamb. Instead of cambering, or curving, the under side of a flat brick arch placed over an opening, the soffit is often made flat and is supported on an iron angle bar. This form of construction is

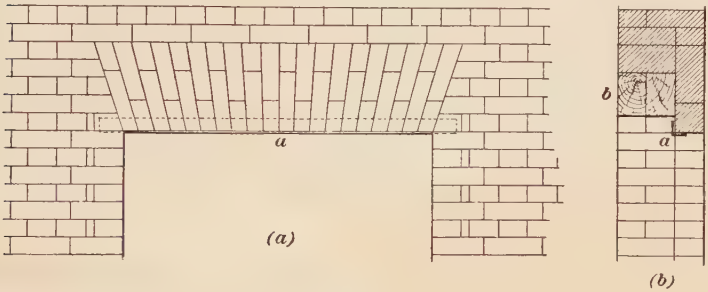


FIG. 29

shown in Fig. 29, in which (*a*) is an elevation of a flat arch over a window opening, the arch being supported by a $1\frac{1}{2}'' \times 1\frac{1}{2}'' \times \frac{1}{4}''$ iron angle, as shown at *a*; (*b*) shows the section through the arch, *a* being the iron angle; *c* the $4\frac{1}{2}$-inch brick arch; and *b* the wooden lintel behind the arch.

80. Trimmer Arches.—**Trimmer arches** are rough arches built to support hearths of fireplace openings, and are shown in *Brickwork*, Part 2.

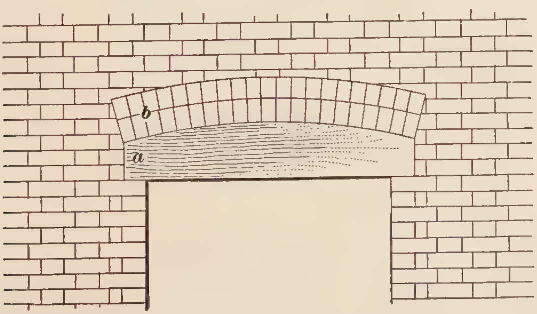


FIG. 30

81. Relieving Arches.—**Relieving arches**, sometimes called **discharging arches**, are usually built over wooden or stone lintels

so that the direct bearing of the wall is taken off the lintels. In Fig. 30 is shown a relieving arch *b* over a wooden lintel *a* when the upper surface of the lintel is cut on a segmental curve to fit the soffit of the arch.

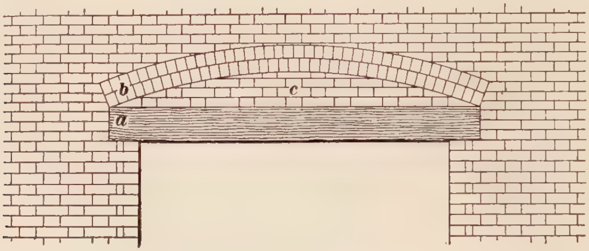


FIG. 31

Should there be any shrinkage of the wooden lintel *a*, there will be no settlement of the brickwork, the arch carrying the weight of the wall placed on it.

82. In some cases, the arch is turned over an ordinary lintel, with the spring of the arch starting from the ends of the lintel, and a core of brickwork is laid between the under side of the arch and the top of the lintel. This is shown in Fig. 31; *a* is the

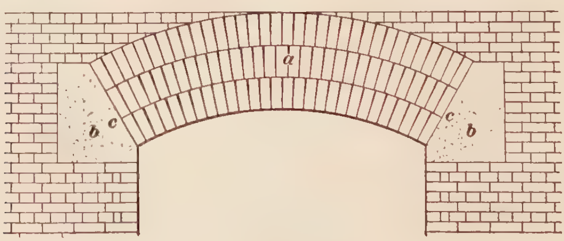


FIG. 32

lintel, which may be either of wood or stone; *b* is the relieving arch, shown in this case as a two-ring arch; and *c* is the brick core between the lintel and the under side of the arch.

83. Brick Segmental Arches.—Fig. 32 gives an example of a **brick segmental arch.** The feature of this arch is that the

intrados curve is less than a semicircle, thus making an angle with the line of the abutment instead of being tangent to it. It is a three-ring arch constructed entirely of common bricks laid as stretchers. This form of arch, unless bonded back into the rear wall with strap iron, is not a strong method of construction. At *a* is shown the three-ring arch; at *b*, the stone springers or skew backs, making an angle with the three rings of the arch at *c*.

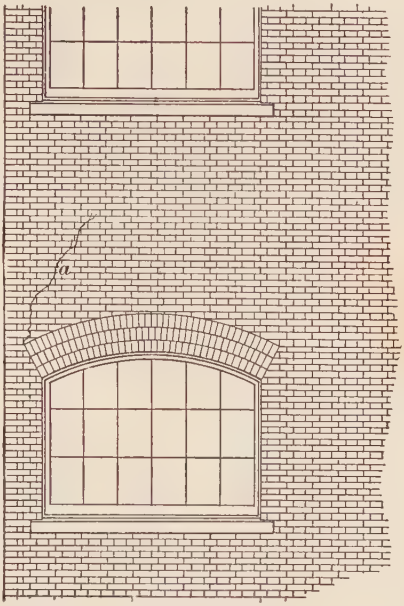


Fig. 33

84. Lateral Thrust in Arches.—In all arches on which weight is imposed, there is a horizontal thrust, or kick, on the brickwork at each side of the arch. So long as the brickwork is strong enough to withstand this thrust, no damage can occur; but, if the arch is placed near the corner of a building a crack is liable to occur in the wall above the arch, unless provision is made to tie in the side wall by means of an iron strap or rod.

Fig. 33 represents an arch near the side of a building where there is no strength in the wall to take up the lateral thrust. The crack *a* is the result.

BRICK VAULTS

85. A **vault** is shown in Fig. 34. It is simply an arch that is long in the direction of its axis. Vaults are constructed in the same manner as arches, with the additional precaution that the bricks are bonded longitudinally, as shown in the figure.

86. Groined Vaults.—An example of an **intersecting, or**

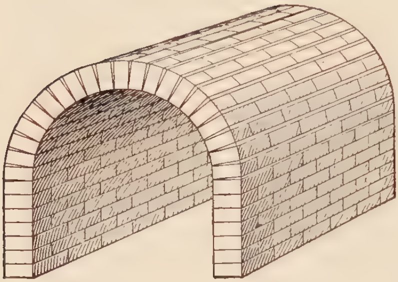


Fig. 34

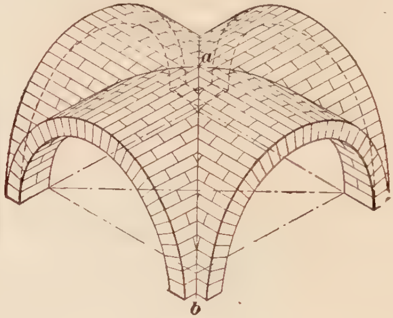


Fig. 35

groined, vault is shown in Fig. 35. This style of vault is often used, although it probably cannot be built as strong as the one shown in Fig. 34, because its strength at the groin *a b* depends entirely on the bond in the brickwork.

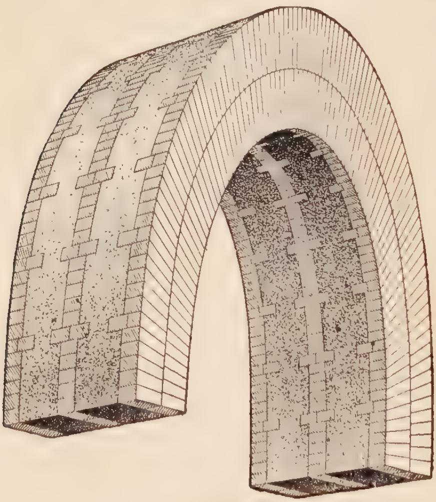


Fig. 36

87. Brick-and-Concrete Vaults.—Vaults formerly were built of brick arches, called **armatures,** with concrete filling. This form of construction, shown in Fig. 36, is good, and is quite easy to erect.

METHODS OF SUPPORTING FLOOR JOISTS

CORBELLING FOR FLOOR JOISTS

88. Brickwork has often to be corbelled out to support floor joists and for other purposes. The corbel usually projects $4\frac{1}{2}$ inches, but sometimes more, and is composed of three or

four courses of brickwork. At *a*, Fig. 37, is shown the brick corbel, *b*, *b* shows the wooden floor joists, *c* is the wall plate, and *d* is the tongued-and-grooved flooring.

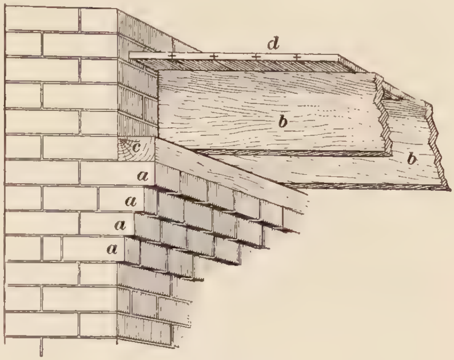


FIG. 37

89. Corbelling out for floor joists has several advantages, one being that, in case of fire, the corbels act as a fire-stop, largely preventing the spread of the flames from story to story; and, in case the floor joists fall, they are inserted such a short distance in the wall that they will not have so much tendency to pull the wall over as if anchored. The wall is also much stronger when corbelled out, for whenever timbers extend into a wall, they lessen the section, or bearing area, by just the amount of space taken up by the ends of the floor joists, and in partition and party walls this is considerable.

HANGERS FOR FLOORBEAMS IN BRICK WALLS

90. Another method of supporting the ends of joists is by the use of joist and girder hangers, which simplifies greatly the work of framing floors. With these hangers and anchors, a good and firm bearing may be had in brick walls. The chief requisite of a good hanger is that it shall hold firmly to the wall and at the same time hold firmly to the joist. Fig. 38 illustrates six styles of hangers used to support joists and beams against brick walls. It will be noted that with none of these six styles does the joist enter the wall. The top part of the hanger is built into the wall and the beam rests in the socket.

In the hangers shown at (*a*) and (*b*), the joist is held in place by one or two spikes or lagscrews driven in through the hole *a* of the hanger and into the wood. In hangers (*c*), (*d*), (*e*), and (*f*),

there is a ridge, or lug, *b* cast on the hanger. A notch is cut across the bottom of the joist and the ridge of metal fits into this notch. The hangers at (*a*) and (*b*) are made of sheet steel stamped and bent into shape, while those shown at (*c*), (*d*), (*e*),

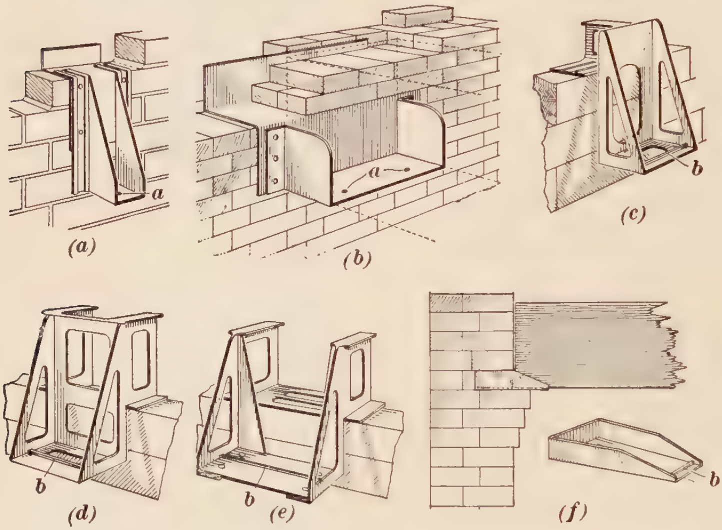


FIG. 38

and (*f*) are made of cast steel. The one shown at (*f*) does not hold to the wall as firmly as some of the other designs, and is generally used above a corbel, as shown in the illustration.

91. Templates.—In Fig. 39 are shown two templates on which the ends of wooden beams in walls may be placed. In (*a*)

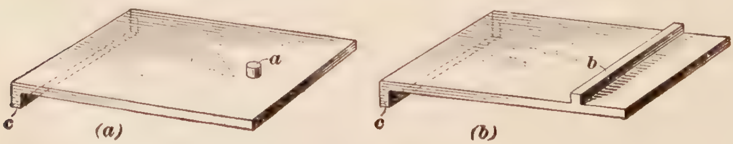


FIG. 39

the teat *a* fits into a hole bored in the bottom of the beam with a brace and bit; while at (*b*) a groove is cut across the entire

bottom of the beam into which the lug *b* fits. The flange *c* is sometimes made to turn up, but a better grip on the wall is had when it turns down, as shown in the illustration.

INSPECTION OF WORK

92. When superintending the erection of brickwork, the architect should see that sufficient mortar is used to fill all the joints. The quality of mortar should be frequently looked after, and nothing but the specified ingredients should be allowed to enter into its composition. The bonding of the walls should be well watched, in order to see that the number of bond courses, specified or required, are put in. Piers should be especially looked after, as their efficiency depends largely on the thoroughness of the bonding.

It should also be seen that the figured dimensions are properly checked and followed; courses kept level and walls plumb; floor anchors securely built in; and that all recesses for soil, vent, heating, and gas pipes are left in the proper places; also, that all unfinished brickwork and stonework is properly protected from the weather.

BRICKWORK

(PART 2)

WALLS, PIERS, AND CHIMNEY BREASTS

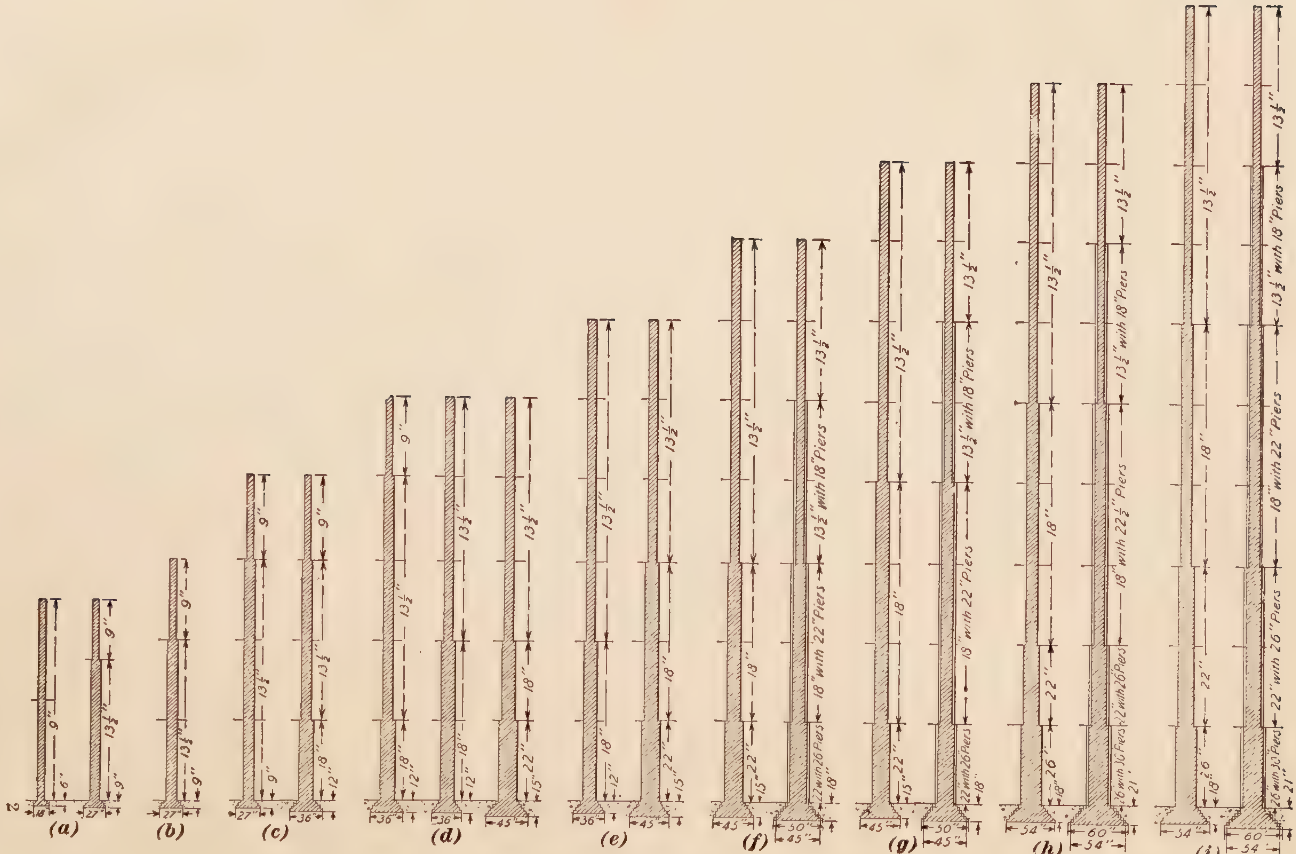
THICKNESS OF BRICK WALLS

1. In order that the design and construction of walls for buildings of various dimensions used for dwellings, warehouses, and other purposes may be carried out intelligently, a knowledge of the thickness of walls required is very important. With this object in mind, an extract is given from the Local Government Board's set of model by-laws that relate to the thickness of brick walls in proportion to their height. As these model by-laws form the basis of the by-laws of most of the city, town, and district councils, and as those not yet based on them are being gradually remodelled to come into line, they may therefore be safely taken as a standard.

WALLS FOR DOMESTIC BUILDINGS

2. Domestic Buildings.—"Domestic building" means a dwelling house or an office building or other outbuilding appurtenant to a dwelling house, whether attached thereto or not, or a shop, or any other building not being a public building or of the warehouse class.

"Domestic house" means a building used or constructed or adapted to be used wholly or principally for human habitation. Every person who shall erect a new domestic building shall construct every external wall and every party wall of such building in accordance with the following rules, and in every case the thickness prescribed shall be the minimum thickness of which any such wall may be constructed, and the several



(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
22" with 26" Piers
18" with 22" Piers
13½" with 18" Piers
26" with 30" Piers
22" with 26" Piers
18" with 22½" Piers

Fig. 1

rules shall apply only to walls built of good bricks, not less than 9 inches long, or of suitable stone, or other blocks of hard and incombustible substance, the beds or courses being horizontal:

(*a*) Where the wall does not exceed 25 feet in height [see Fig. 1 (*a*)] its thickness shall be as follows:

If the wall does not exceed 30 feet in length, and does not comprise more than two stories, it shall be 9 inches thick for its whole height.

If the wall exceeds 30 feet in length, or comprises more than two stories, it shall be $13\frac{1}{2}$ inches thick below the topmost story and 9 inches thick for the rest of its height.

(*b*) Where the wall exceeds 25 feet but does not exceed 30 feet in height [see Fig. 1 (*b*)] it shall be $13\frac{1}{2}$ inches thick below the topmost story and 9 inches thick for the rest of its height.

(*c*) Where the wall exceeds 30 feet but does not exceed 40 feet in height [see Fig. 1 (*c*)] its thickness shall be as follows:

If the wall does not exceed 35 feet in length it shall be $13\frac{1}{2}$ inches thick below the topmost story and 9 inches thick for the rest of its height.

If the wall exceeds 35 feet in length it shall be 18 inches thick from the base for the height of one story, then $13\frac{1}{2}$ inches thick for the rest of its height below the topmost story, and 9 inches thick for the rest of its height.

(*d*) Where the wall exceeds 40 feet but does not exceed 50 feet in height [see Fig. 1 (*d*)] its thickness shall be as follows:

If the wall does not exceed 30 feet in length it shall be 18 inches thick for the height of one story, then $13\frac{1}{2}$ inches thick for the rest of its height below the topmost story, and 9 inches thick for the rest of its height.

If the wall exceeds 30 feet but does not exceed 45 feet in length it shall be 18 inches thick for the height of two stories, then $13\frac{1}{2}$ inches thick for the rest of its height.

If the wall exceeds 45 feet in length it shall be 22 inches thick for the height of one story, then 18 inches thick for the height of the next story, and $13\frac{1}{2}$ inches thick for the rest of its height.

(*e*) Where the wall exceeds 50 feet but does not exceed 60 feet in height [see Fig. 1 (*e*)] its thickness shall be as follows:

If the wall does not exceed 45 feet in length it shall be 18 inches thick for the height of two stories and $13\frac{1}{2}$ inches thick for the rest of its height.

If the wall exceeds 45 feet in length it shall be 22 inches thick for the height of one story, then 18 inches thick for the height of the next two stories, and then $13\frac{1}{2}$ inches thick for the rest of its height.

(*f*) Where the wall exceeds 60 feet but does not exceed 70 feet in height [see Fig. 1 (*f*)] its thickness shall be as follows:

If the wall does not exceed 45 feet in length it shall be 22 inches thick for the height of one story, then 18 inches thick for the height of the next two stories, and then $13\frac{1}{2}$ inches thick for the rest of its height.

If the wall exceeds 45 feet in length it shall be increased in thickness in each of the stories below the uppermost two stories by $4\frac{1}{2}$ inches (subject to the provision hereinafter contained respecting distribution in piers).

(*g*) Where the wall exceeds 70 feet but does not exceed 80 feet in height [see Fig. 1 (*g*)] its thickness shall be as follows :

If the wall does not exceed 45 feet in length it shall be 22 inches thick for the height of one story, then 18 inches thick for the height of the next three stories, and $13\frac{1}{2}$ inches thick for the rest of its height.

If the wall exceeds 45 feet in length it shall be increased in thickness in each of the stories below the uppermost two stories by $4\frac{1}{2}$ inches (subject to the provision hereinafter contained respecting distribution in piers).

(*h*) Where the wall exceeds 80 feet but does not exceed 90 feet in height [see Fig. 1 (*h*)] its thickness shall be as follows :

If the wall does not exceed 45 feet in length it shall be 26 inches thick for the height of one story, 22 inches thick for the height of the next story, 18 inches thick for the height of the next three stories, and $13\frac{1}{2}$ inches thick for the rest of its height.

If the wall exceeds 45 feet in length it shall be increased in thickness in each of the stories below the uppermost two stories by $4\frac{1}{2}$ inches (subject to the provision hereinafter contained respecting distribution in piers).

(*i*) Where the wall exceeds 90 feet but does not exceed 100 feet in height [see Fig. 1 (*i*)] its thickness shall be as follows :

If the wall does not exceed 45 feet in length it shall be 26 inches thick for the height of one story, 22 inches thick for the height of the next two stories, 18 inches thick for the height of the next three stories, and $13\frac{1}{2}$ inches thick for the rest of its height.

If the wall exceeds 45 feet in length it shall be increased in thickness in each of the stories below the uppermost two stories by $4\frac{1}{2}$ inches (subject to the provision hereinafter contained respecting distribution in piers).

(*j*) If any story exceeds in height sixteen times the thickness prescribed for its walls, the thickness of each external wall and of each party wall throughout that story shall be increased to one-sixteenth part of the height of the story, and the thickness of each external wall and of each party wall below that story shall be proportionately increased (subject to the provision hereinafter contained respecting distribution in piers).

(*k*) Every external wall and every party wall of any story which exceeds 10 feet in height shall be not less than $13\frac{1}{2}$ inches in thickness.

(*l*) Where by any of the foregoing rules relating to the thickness of external walls and party walls of domestic buildings an increase of thickness is required in the case of a wall exceeding 60 feet in height and 45 feet in length, or in the case of a story exceeding in height sixteen times the thickness prescribed for its walls, or in the case of a wall below that story, the increased thickness may be confined to piers properly distributed, of which the collective widths amount to one-fourth part of the length

of the wall. The width of the piers may nevertheless be reduced if the projection is proportionately increased, the horizontal sectional area not being diminished; but the projection of any such pier shall in no case exceed one-third of its width.

WALLS FOR PUBLIC BUILDINGS

3. Public Buildings.—"Public building" means a building used or constructed or adapted to be used, either ordinarily or occasionally, as a church, chapel, or other place of public worship, or as a hospital, workhouse, college, school (not being merely a dwelling house so used), theatre, public hall, public concert room, public ball-room, public lecture room, or public exhibition room, or as a public place of assembly for persons admitted thereto, by tickets or otherwise, or used or constructed or adapted to be used, either ordinarily or occasionally, for any other public purpose.

"Building of the warehouse class" means a warehouse, factory, manufactory, brewery, or distillery.

Every person who shall erect a new public building or a new building of the warehouse class shall construct every external wall and every party wall of such building in accordance with the following rules; and in every case the thickness prescribed shall be the minimum thickness of which any such wall may be constructed, and the several rules shall apply only to walls built of good bricks, not less than 9 inches long, or of suitable stone or other blocks of hard and incombustible substance, the beds or courses being horizontal:

(*a*) Where the wall does not exceed 25 feet in height (whatever its length) it shall be $13\frac{1}{2}$ inches at its base [see Fig. 2 (*a*)].

(*b*) Where the wall exceeds 25 feet but does not exceed 30 feet in height [see Fig. 2 (*b*)] it shall be at its base of the thickness following:

If the wall does not exceed 45 feet in length it shall be $13\frac{1}{2}$ inches thick at its base.

If the wall exceeds 45 feet in length it shall be 18 inches thick at its base.

(*c*) Where the wall exceeds 30 feet but does not exceed 40 feet in height [see Fig. 2 (*c*)] it shall be at its base of the thickness following:

If the wall does not exceed 35 feet in length it shall be $13\frac{1}{2}$ inches thick at its base.

If the wall exceeds 35 feet but does not exceed 45 feet in length it shall be 18 inches thick at its base.

If the wall exceeds 45 feet in length it shall be 22 inches thick at its base.

(*d*) Where the wall exceeds 40 feet but does not exceed 50 feet in height [see Fig. 2 (*d*)] it shall be at its base of the thickness following:

If the wall does not exceed 30 feet in length it shall be 18 inches thick at its base.

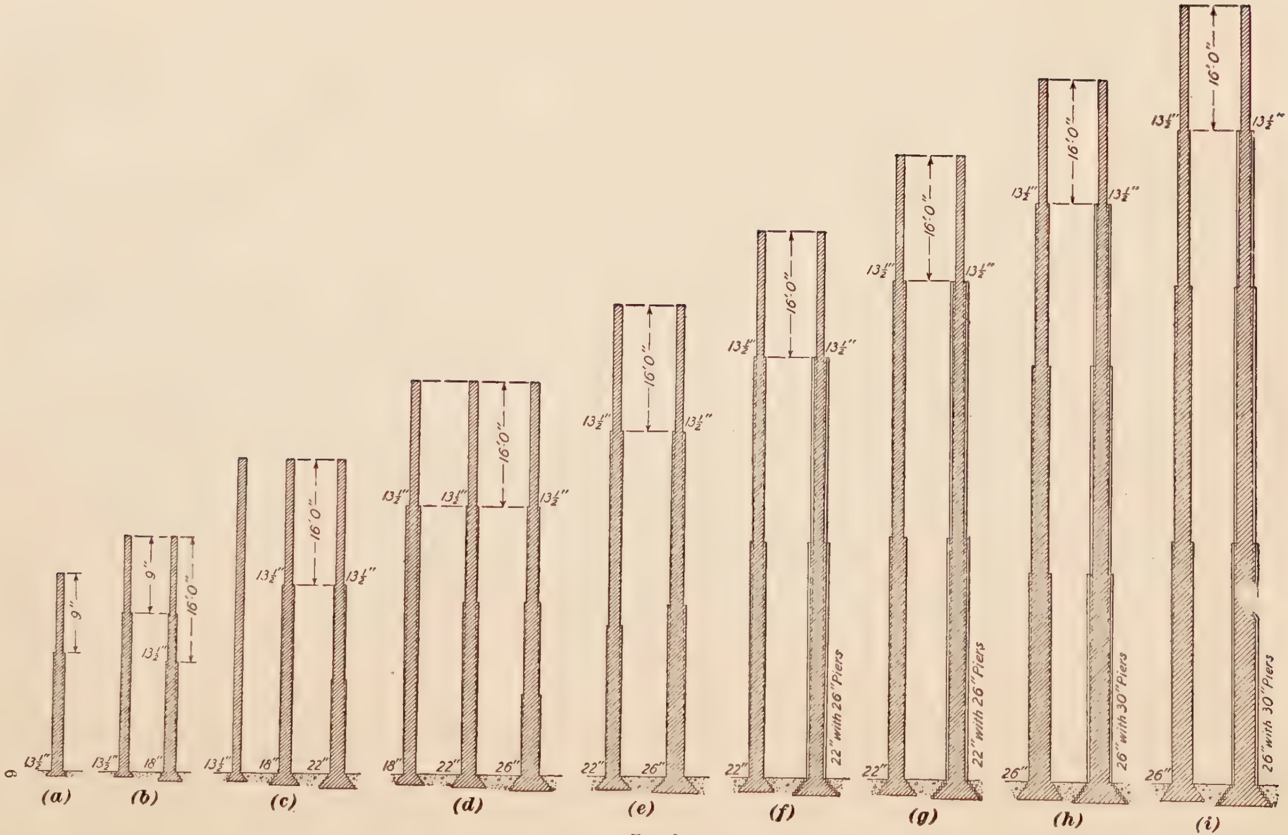


FIG. 2

If the wall exceeds 30 feet but does not exceed 45 feet in length it shall be 22 inches thick at its base.

If the wall exceeds 45 feet in length it shall be 26 inches thick at its base.

(*e*) Where the wall exceeds 50 feet but does not exceed 60 feet in height [see Fig. 2 (*e*)] it shall be at its base of the thickness following :

If the wall does not exceed 45 feet in length it shall be 22 inches thick at its base.

If the wall exceeds 45 feet in length it shall be 26 inches thick at its base.

(*f*) Where the wall exceeds 60 feet but does not exceed 70 feet in height [see Fig. 2 (*f*)] it shall be at its base of the thickness following :

If the wall does not exceed 45 feet in length it shall be 22 inches thick at its base.

If the wall exceeds 45 feet in length it shall be increased in thickness from the base up to within 16 feet from the top of the wall by $4\frac{1}{2}$ inches (subject to the provision hereinafter contained respecting distribution in piers).

(*g*) Where the wall exceeds 70 feet but does not exceed 80 feet in height [see Fig. 2 (*g*)] it shall be at its base of the thickness following :

If the wall does not exceed 45 feet in length it shall be 22 inches thick at its base.

If the wall exceeds 45 feet in length it shall be increased in thickness from the base up to within 16 feet from the top of the wall by $4\frac{1}{2}$ inches (subject to the provision hereinafter contained respecting distribution in piers).

(*h*) Where the wall exceeds 80 feet but does not exceed 90 feet in height [see Fig. 2 (*h*)] it shall be at its base of the thickness following :

If the wall does not exceed 45 feet in length it shall be 26 inches thick at its base.

If the wall exceeds 45 feet in length it shall be increased in thickness from the base up to within 16 feet from the top of the wall by $4\frac{1}{2}$ inches (subject to the provision hereinafter contained respecting distribution in piers).

(*i*) Where the wall exceeds 90 feet but does not exceed 100 feet in height (see Fig. 2 (*i*)] it shall be at its base of the thickness following :

If the wall does not exceed 45 feet in length it shall be 26 inches thick at its base.

If the wall exceeds 45 feet in length it shall be increased in thickness from the base up to within 16 feet from the top of the wall by $4\frac{1}{2}$ inches (subject to the provision hereinafter contained respecting distribution in piers).

(*j*) The thickness of the wall at the top, and for 16 feet below the top, shall be $13\frac{1}{2}$ inches, and the intermediate parts of the wall between the base and 16 feet below the top shall be built solid throughout the space between straight lines drawn on each side of the wall and joining the

thickness at the base to the thickness at 16 feet below the top. Nevertheless, in walls not exceeding 30 feet in height the walls of the topmost story may be 9 inches thick, provided the height of that story does not exceed 10 feet.

(*k*) If any story exceeds in height fourteen times the thickness prescribed for its walls the thickness of each external wall and of each party wall throughout that story shall be increased to one-fourteenth part of the height of the story, and the thickness of each external wall and of each party wall below that story shall be proportionately increased (subject to the provision hereinafter contained respecting distribution in piers).

(*l*) Every external wall and every party wall of any story which exceeds 10 feet in height shall be not less than $13\frac{1}{2}$ inches in thickness.

(*m*) Where by any of the foregoing rules relating to the thickness of external walls and party walls of public buildings, or buildings of the warehouse class, an increase of thickness is required in the case of a wall exceeding 60 feet in height and 45 feet in length, or in the case of a story exceeding in height fourteen times the thickness prescribed for its walls, or in the case of a wall below that story, the increased thickness may be confined to piers properly distributed, of which the collective widths amount to one-fourth part of the length of the wall. The width of the piers may nevertheless be reduced if the projection is proportionately increased, the horizontal sectional area not being diminished; but the projection of any such pier shall in no case exceed one-third of its width.

NOTE.—The walls for public buildings are not built with tapering sides as described in Art. **3** (*j*). The straight dotted lines shown in Fig. 2 on each side of the wall and joining the thickness at its base to the thickness at 16 feet below its top simply indicate that the wall at no part of its height must be of less thickness than that contained within the dotted lines. The requirements of this clause are carried out by building the wall with vertical sides and reducing its thickness by means of offsets as shown.

TYPES OF BRICK WALLS

4. Solid Walls.—The solid brick walls of a building are not waterproof. A driving rainstorm of several days' duration will sometimes penetrate even a $1' \ 10\frac{1}{2}''$ wall and, by wetting the inside surfaces, spoil whatever interior coverings the wall may have. In solid brickwork there is always a lack of insulation against heat and moisture. Air is about the best, and certainly the cheapest, form of insulation. To obtain air insulation, several methods are resorted to. The one which until quite recently was most in use consists in furring the inner surface of outside brick walls with furring strips of wood, and then fastening the lath and plaster to these strips. The danger of fire spreading

from floor to floor through the spaces between the furring strips, especially in hospitals, schools, and isolated private residences, has caused many authorities to recommend the use of hollow walls of brick in their stead.

5. **Hollow Walls.**—Hollow walls are intended to keep moisture from passing through, and, by providing an air space, to keep the building cooler in summer and warmer in winter. Difficulties that largely offset their advantages are met with in construction, however, so that hollow walls are not in general use throughout the British Isles. The objections to hollow walls, in addition to the difficulty of preserving the cavity throughout in construction, are that more ground area is required and the cost is considerably increased.

In the construction of hollow walls of brickwork two distinct walls are built, parallel with one another and separated by a cavity about $2\frac{1}{4}$ inches wide throughout, the thickness of the inner wall depending on the height and length of the wall and the superimposed loads, the outer wall being usually $4\frac{1}{2}$ inches thick. The two walls are securely connected by special bonding ties of metal or glazed stoneware, built in at distances apart not exceeding 3 feet horizontally and 18 inches vertically. The cavity should be ventilated by means of air bricks near the base and head of the wall, and should extend at least 3 inches below the damp-proof course. Where lintels over openings extend across the cavity, they should be protected above the head by strips of lead or asphalt, forming a channel for conducting moisture away from the lintel.

6. **Party Walls.**—A **party wall** is a wall that separates two adjoining buildings, and sometimes carries the floor and roof beams of one or both of them. A party wall is sometimes owned jointly by the two persons who own adjacent property, in which case the centre line of the party wall marks one of the boundary lines of the site, or the right to use the wall for the support of floor and roof beams may be purchased at the time of the erection of an adjoining building.

The floor loads on party walls are therefore sometimes twice as great as the load on any outside wall; besides this, the necessity

for thorough and complete protection from fire is greater in party walls than in outside walls, because those on the outside can easily be reached in case of fire, while party walls, being enclosed by other walls, are more difficult of access. As building regulations differ materially in regard to the thickness of party walls, they are usually made the same thickness in each story as outside walls; the Local Government Board's model by-laws, for instance, treat them as external walls, so far as thickness is concerned.

7. Curtain Walls.—In modern steel-frame or skeleton construction, used largely in the Colonies and in America, the floor loads in a building are carried on the steel frame, and the walls carry no load other than their own weight. There are a few high buildings in which the walls extend down to the foundations, but because it is desired to make these walls thin on account of the space they occupy and the high price of property in the business sections of cities, curtain walls are generally supported on the steel frame of such buildings, usually at every floor. In this way much thinner walls can be used and valuable space saved.

8. The following is an extract from the London County Council General Powers Act 1909, which regulates the general thickness of curtain and other enclosing walls of buildings of steel frame construction.

Section 22. Sub-section 11 (*a*). An external wall may be of any thickness not less than $8\frac{1}{2}$ inches for the topmost 20 feet of its height and 13 inches for the remainder of its height below such topmost 20 feet . . .

(*b*) All party walls shall be of the thickness prescribed by the principal Acts.

9. Veneered Walls.—In the Colonies, frame houses are frequently encased in a $4\frac{1}{2}$-inch veneer of brickwork, which is usually placed directly against the wood, but preferably should be separated from it by a 2-inch air space. Veneered walls are cheaper than those built of solid brick. Houses constructed in this fashion are warmer in winter and cooler in summer, and are also less likely to catch fire from outside sources than are ordinary frame buildings. It is not to be construed, however, that a veneered wall is better than a solid brick wall, for it really will last no longer than the wooden frame that it covers.

TERRA-COTTA FURRING

10. A common form of construction, in the Colonies and America, especially in fireproof and waterproof walls, is one in which either terra-cotta blocks or hollow bricks are used.

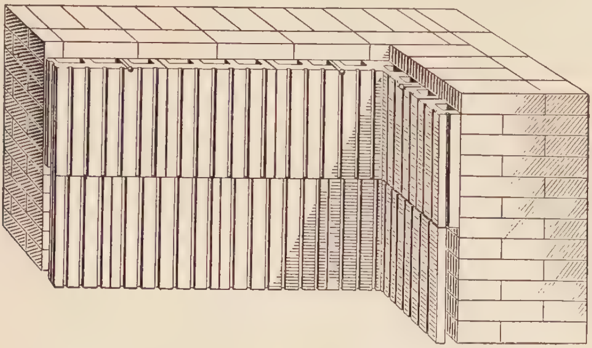


FIG. 3

Although not adopted in the British Isles, this method has certain advantages which are worth consideration.

In Fig. 3 is shown a wall that is furred with hollow blocks, which are usually $1\frac{1}{2}$ or 2 inches thick and 12 inches square.

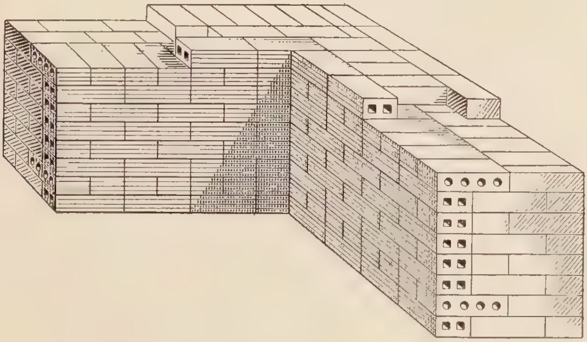


FIG. 4

They are laid in gauged mortar, and are held in position by nails being driven through every other block into a joint in the brickwork.

A wall furred with hollow bricks is illustrated in Fig. 4. Special bricks are made for headers, so that the holes in the bricks will all run the same way. The hollow bricks are made of porous terra-cotta, so that nails can be driven into them. They are therefore not entirely waterproof ; but in thick walls, where the conditions are favourable, they are sufficiently dense to exclude all moisture. Both the hollow bricks and the 12-inch square blocks are grooved on the face, as shown, to provide a key for the plaster.

OPENINGS IN WALLS

11. Openings in Solid Walls.—When a brick wall contains door and window openings, their relative position should be very carefully considered, not only with regard to convenience and symmetry, but also with regard to their effect on the strength of the wall. When walls are broken frequently by windows and other openings, cracks are more likely to occur than when the wall is plain and unbroken. This is owing to the unequal pressure on the mortar joints. If walls are well bonded and anchored, the danger of cracks may be reduced to a minimum.

In any bearing wall carrying the ends of floor joists, the combined width of openings should not be more than one-third the total length of the wall, unless the thickness of the wall between the windows is increased by the use of piers, pilasters, or buttresses. When possible, the window openings in the different stories should be placed directly over one another.

Unless absolutely necessary, the placing of windows under a pier or directly over a narrow mullion should always be avoided. The effect of such an arrangement is shown in Fig. 5. At *a* is shown a window opening under a pier ; the combined effects of the load of brickwork and the settlement of the joints cause the sills of the upper windows and the lintel of the lower window to crack, and the cracks extend through the brickwork. At *b*, *b*, the weight of the brickwork pressing on each side of the wall over the window mullion concentrates the weight on the centre of the lintel *c* and mullion *d*, and causes both of them to crack.

If it is found absolutely necessary to place windows in the positions shown in Fig. 5, steel beams should be placed over

the windows *b* to carry the load and prevent the lintels and sills from cracking. Of course, the liability to crack is much greater in a high building than in a low one.

Fig. 5

12. Openings in Hollow Walls.—Fig. 6 shows the construction of a hollow wall round a window opening; *a* shows the outside $4\frac{1}{2}$-inch wall; *b*, the $2\frac{1}{4}$-inch air space; *c*, the inner wall, $13\frac{1}{2}$ inches thick on the ground floor and 9 inches thick on the

upper floor; *d*, the wall below the damp-proof course; *e*, the window sill; *f*, the stone window head; *g*, the steel and concrete lintel over the window opening; *h*, the lead covering on top of the lintel, to prevent any moisture from passing through the hollow space on to the window head; *j*, the wrought-iron wall ties that bond the inner and outer walls together; *k*, the first-floor joists; *l*, the ground-floor joists, resting on the plates *o* and *p*; *m*, the damp-proof course; and *n*, the ventilating air brick.

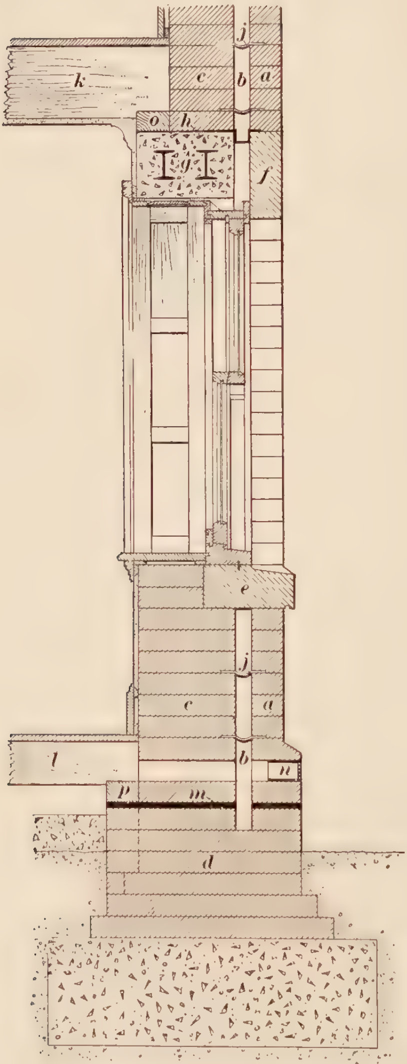


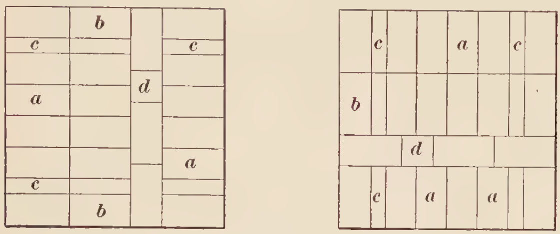
FIG. 6

BRICK PIERS

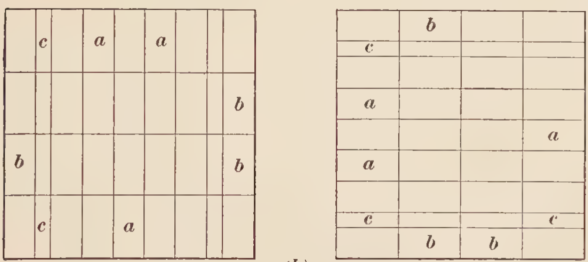
13. Brick piers are built in the same manner as brick walls. They should always be properly bonded together in English bond in the strongest manner possible. The height of isolated brick piers should not exceed twelve times their least square dimension.

The object of bonding a pier carrying a heavy weight is to distribute the load over the whole area, thereby causing the load to bear equally on each brick used in the construction.

In Fig. 7 (*a*) and (*b*) are shown plans of alternate courses in brick piers of different sizes. At (*a*) are shown the two alternate courses of a $3\frac{1}{2}$-brick pier built in English bond. The face headers are shown at *a* and stretchers at *b*. To get the proper



(*a*)



(*b*)

Fig. 7

bond, queen closers are inserted as at *c* and half bats are inserted at *d*.

In (*b*) are shown the two alternate courses of a 4-brick pier, where the letters refer to the same parts as described in (*a*).

BRICK NOGGING

14. Stud partitions in brick buildings and the spaces between the outside studs in wooden-framed houses are often filled with brickwork, to obstruct as much as possible the passage of fire, sound, and vermin. As there is no special weight placed on the brick, the cheapest quality may be used for this purpose, such

as the pale or salmon bricks from the outer portion of a brick kiln. The bricks should be laid in mortar as in a $4\frac{1}{2}$-inch brick wall, and are often laid on edge, being then 3 inches thick.

When the wall is lathed with wooden laths, there should be a small space left between the brick nogging and the laths, so that the plaster will have sufficient room for a key.

BEDDING WOOD IN BRICKWORK

15. It was at one time the practice to build timber into walls of brickwork or masonry for the purpose of attaching carpentry, joinery, etc. This should be avoided wherever possible, because the wall is weakened by being reduced in bearing area, and the timber will shrink and be liable to attack by dry rot. A much better plan is to insert special fixing bricks in the wall at intervals, and then to nail the woodwork directly to the fixing brick. Fixing bricks of breeze concrete, porous terra-cotta, and other materials can be obtained in the sizes of ordinary bricks, which will hold a nail as securely as will wood.

CHIMNEYS AND FIREPLACES

16. General Considerations.—One of the most important things to be considered in the design of a house is the correct position, area, and height of the chimneys. To make the chimney draw properly, a separate flue should be provided, extending from each fireplace to the top of the chimney. The furnace, where this type of heater is used, in the basement and the kitchen range may, however, connect with the same flue, and, as the range fire heats the flue and is above the furnace, the furnace draught is often better when thus arranged.

17. The fireplaces must be properly arranged for convenience, and, where possible, should be grouped together for economy, and because the efficiency of the flues is thus increased. All fireplaces should be carefully drawn and figured on the plans and sections, and provision should be made for the proper support of the chimney stacks in which they are placed, by building

suitable foundations in the basement. The flues should be constructed to run in curves as easy as possible up to the roof, and the stacks should rise sufficiently above the adjoining roofs or walls. The points at which the stacks pierce the roof planes require consideration. The roof lines may be so placed in the preliminary sketches that the chimney stacks cut through a valley or a hip, destroying the grouping of the roof planes as well as weakening the framework of the roof. Where a stack cuts through a valley, it forms a permanent obstacle to the immediate passage of the rain-water toward the gutter, and forms a barrier for the retention of snow, which piles up in a mass behind it.

18. Proportion and Construction of Flues.—The customary size of flues for ordinary fireplaces is 9 inches by 9 inches, and for larger fireplaces and kitchen ranges is $13\frac{1}{2}$ inches by 9 inches, these sizes being sufficient in area, and convenient in bonding brickwork. Fire-places are frequently placed back to back on the same story. Where they are situated immediately over each other, as in the upper stories, it is necessary to divert the upward direction of the lower flues either to one side or the other in order to avoid the niche for the fireplace above. The divergence should be gradual, and is best effected by the introduction of bends connected by curves of large radii, thereby reducing the friction in the flues. The friction is considerable when sharp angular offsets are formed. The bent or curved flues are considered preferable to those that are perfectly straight, because they prevent rain and sleet from falling vertically on the fire, while they also tend to check the downward passage of currents of cold air, called *down draughts*. The divergence, to be effective, should be such that daylight cannot be seen when one looks up the flue.

Where it is impracticable to construct the flue with a deviating curve, and a vertical line must be followed, it will be found expedient to place a solid cover on top of the chimney, and to arrange for smoke outlets on the sides of the stack. This method of construction will prevent rain and sleet from descending the chimney, and the walls of the flue will thus be kept drier than

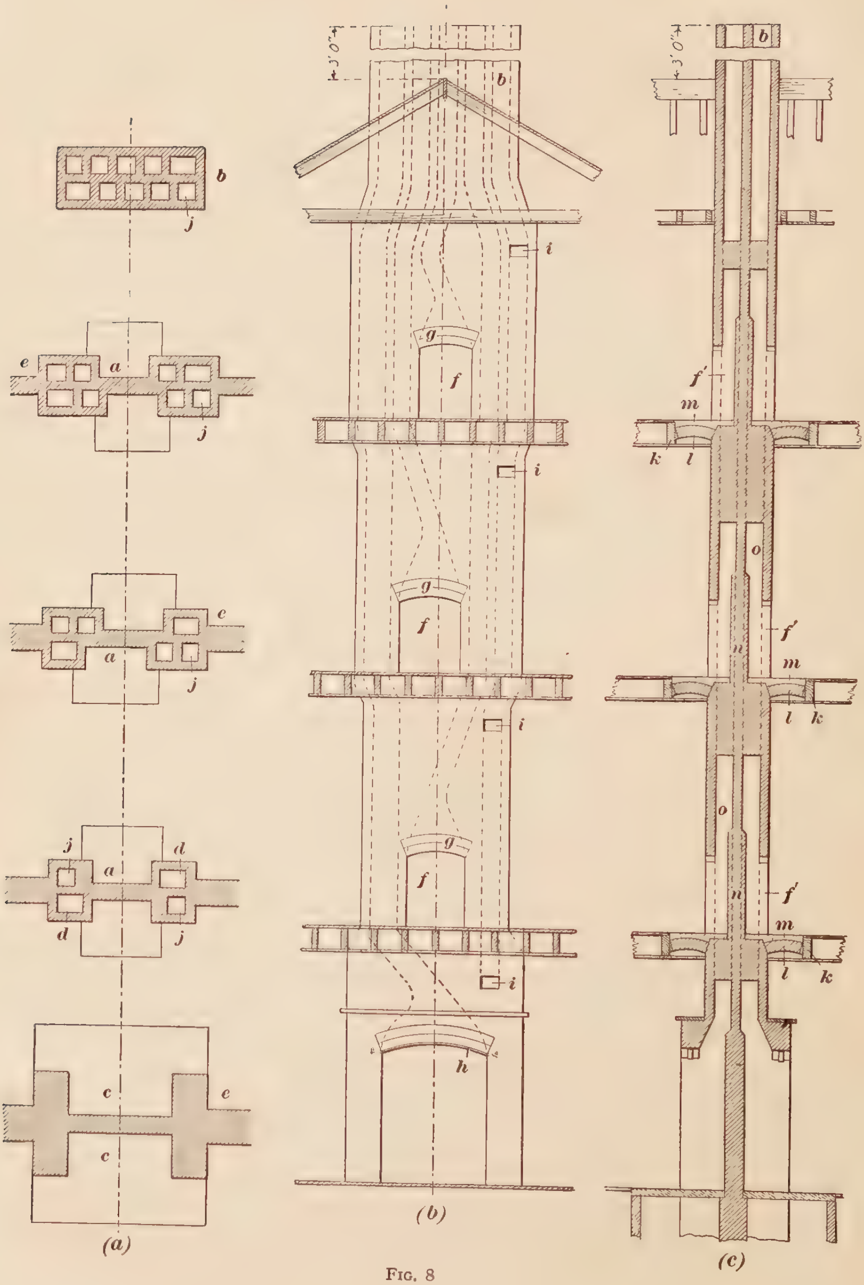

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Fig. 8

would otherwise be the case. It is necessary to exclude rain and snow from a chimney flue, as the presence of any moisture will seriously affect the draught.

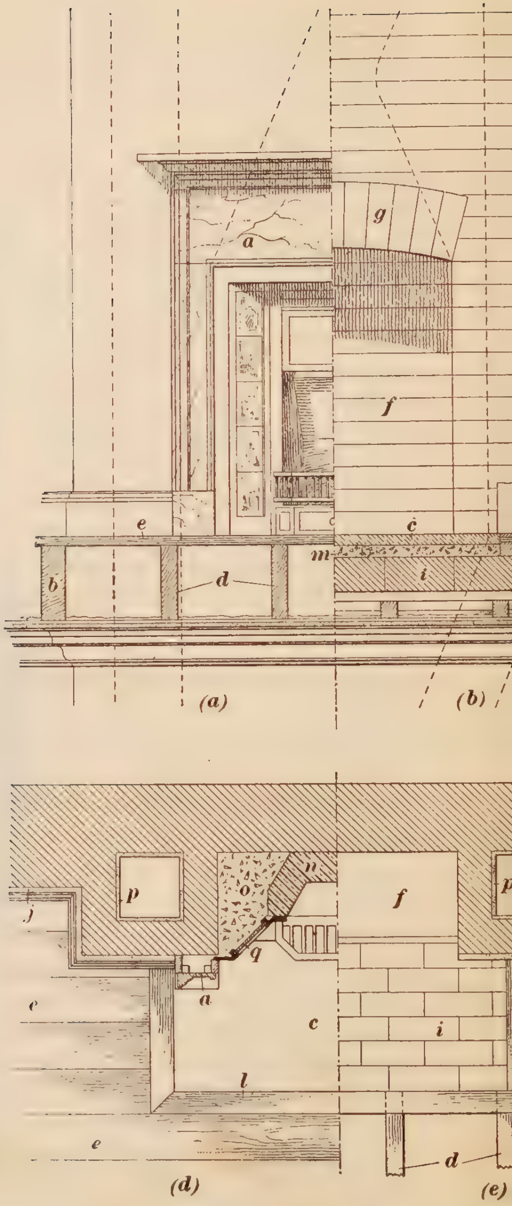
19. Arrangement and Construction of Fireplaces.—The arrangement of fireplaces and flues in a building of four stories is illustrated in plan, elevation, and section in Fig. 8 (*a*), (*b*), and (*c*), respectively. The fireplaces *a*, *a*, six in number, are shown back to back on each floor, upon the wall separating two rooms, the flues being grouped into one chimney stack *b*, which rises 3 feet above the ridge of the roof. The lowest fireplace openings *c c* are intended to receive a kitchen cooking-range, and are, in consequence, of greater depth than the recesses for the upper fireplaces, the flues *d* also being larger, or $13\frac{1}{2}$ inches by 9 inches, while those from *a a* are only 9 inches by 9 inches. The chimney stack should be constructed on a solid and sufficient foundation, with footings similar to those of the adjoining walls. Where chimney stacks do not extend to the ground, however, they may be built on corbels of brick, stone, or similar incombustible material, or on a metal girder. That portion of a chimney stack which projects into the room, and shown at *e*, is called the chimney breast, and varies, of course, in dimensions with the size of the fireplace opening, the width of the jambs, and the number and size of flues to be accommodated. Where flues must be constructed at an angle less than 45° with the horizon, the brickwork forming the upper side of each flue must be at least 9 inches thick, and a proper soot-door for the purpose of gaining access to the flue to remove the soot must be provided, at least 15 inches from any woodwork.

In (*b*) the fireplace openings are shown at *f*, and the flues from them are shown running up to the chimney stack by dotted lines ; the upper-floor fireplace openings have a brick arch turned over them, as at *g g*, while the lower, or kitchen, fireplace opening shown at *c* in (*a*) has a chimney bar *h* to support the arch, as it is of larger span. At *i* is shown the ventilating flue running from each room to the open air, and joining on each floor to the vent flue *j*, shown in (*a*). In (*c*) is shown a section through the chimney stack where the fireplace openings

are shown at *f′*, the trimmer to the floor joists is shown at *k*, with the brick arch *l* carrying the hearth *m*. It will be noticed that there is 9 inches of brickwork between the fireplace backs, as shown at *n*, but this is splayed off to $4\frac{1}{2}$ inches between the flues, as shown at *o*.

20. As fireplaces and flues generally require more depth than can be obtained in the thickness of ordinary walls, it is necessary to construct the breast of such additional thickness as may be required to accommodate the grate. The increased thickness may project either on the exterior or the interior of the wall. When the projection is made on the exterior, it does not reduce the size of the room and permits the construction of a straight interior wall surface. In many cases the exterior projection is so treated that the chimney throughout its height is emphasized and made to form a striking and effective feature on the elevations of the buildings. However, this is often sacrificed on the score of economy in the cost of execution, as when the projection is made on the interior of the wall there is little extra cost, and at times it is desirable to accentuate the vertical lines of the stack in the apartment.

21. In Fig. 9 are shown the details of a fireplace opening in a chimney breast. At (*a*) is shown half an elevation of the completed fireplace with the mantelpiece *a* fixed complete. A section through the floor is also shown, where *b* is the trimming joist for the hearth *c*, and *d* is one of the joists carrying the floor; the floor boards are shown at *e*. In (*b*) a half-elevation of the brick finishings to the fireplace opening and section through the arch carrying the hearth is shown. The fireplace opening is shown at *f* with the brick arch over same at *g*. Where an arch such as this is used and the brick jambs *h* are of less width than $13\frac{1}{2}$ inches, they must be tied in with an iron bar 17 or 18 inches longer than the width of the opening, its ends being turned down and built into the joints in the brickwork. At *b* is shown the trimming joist, at *i* the brick arch carrying the hearth *c*, and at *j* is shown the plaster on the wall. In (*c*) is shown a section through the fireplace, and in (*d*) is shown a half-plan through the fireplace and mantelpiece with the flooring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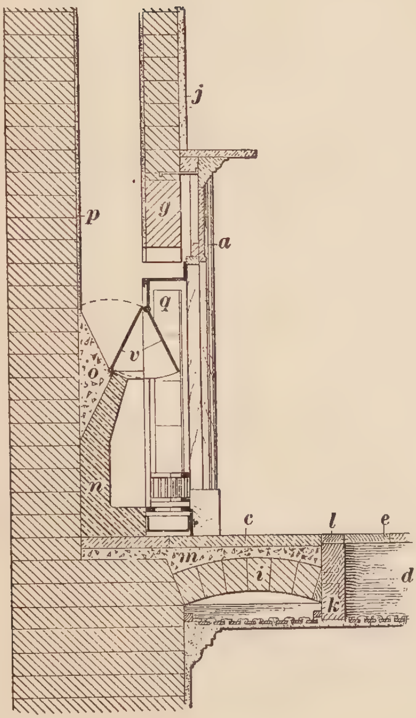


(c)

and hearth laid complete, while in (*e*) is shown a half-plan with the flooring removed to show the construction. The letters in the following description refer to parts in the plans (*d*), (*e*), as well as to the same parts in section in (*c*). At *c* is shown the hearth to the chimney opening, which must be of incombustible material at least 6 inches longer at each side than the width of the opening, and projecting at least 18 inches in front of the chimney breast. On the lowest floor this hearth may be bedded on concrete, but on upper floors the hearth should be laid on stone or iron bearers, a brick trimmer arch such as that shown at *i*, or other incombustible material. This trimmer arch *i* is built off the trimmer *k*, a splayed block being fixed to same to give the necessary bearing. The brickwork of the wall is splayed off to give the necessary bearing to the other side of the arch. Round the hearth, which may be finished in tiles or cement, a hardwood slip or border *l* is fixed, so as to give a neat finish between the floor boards *e* and the hearth *c*.

22. In Fig. 9 the floor joists *d* are framed so that the portion of the floor system in front of the fireplace is carried by the trimming joists *b*, *b*, which, in the event of flues passing through the jambs in the fireplace, would be kept 2 inches clear of the brickwork. The trimmer *k* carries the trimmed joists *d*, *d*, and is supported itself by the trimming joists *b*, *b*. The junctions may be made by mortising and tenoning them together, or they may be hung in stirrup irons.

A temporary wooden centre is placed to support the trimmer arch *i* during construction, the function of the arch being to carry the hearth free and clear of any woodwork. The depth of the arch is $4\frac{1}{2}$ inches.

The extrados of the arch is levelled up with cement concrete, as shown at *m*, Fig. 9, preparatory to receiving the hearth, which may be a slab of polished slate or composed of plain or enamelled tiling, or may be finished in cement. At *n* is shown the firebrick backing to the chimney opening in which the fire is made, backed up against the brickwork by the concrete *o*. At *p* is shown the parging to the flue, while at *j* is shown the general plastering to the walls of the room. The

chimneypiece is shown at *a*, and the interior, which can be of any design desired, at *q*.

23. The opening above the fireplace is contracted like an inverted funnel, or hopper, so as to guide the ascending current of heated air and smoke toward the inlet to the flue proper. The funnel-shaped contraction, called the *throat*, is formed by drawing over the brickwork as shown by the dotted lines over the fireplace opening *f* in Fig. 9 (*a*) and (*b*), each course of bricks adjacent to the opening being corbelled, or made to advance slightly in front of the course immediately underneath it. The lower corners of the bricks are cut off with the edge of the bricklayer's trowel, and the corbelling follows a curved outline up to the neck, or inlet, of the flue proper.

The effectiveness of a flue depends largely on the temperature of the gases flowing through it; therefore, the height of the opening over the fire should be restricted to about 30 inches, so that the cold air from the room may not readily pass up the flue without first coming in contact with the fire.

24. A depth of $13\frac{1}{2}$ inches in the fire opening is usually

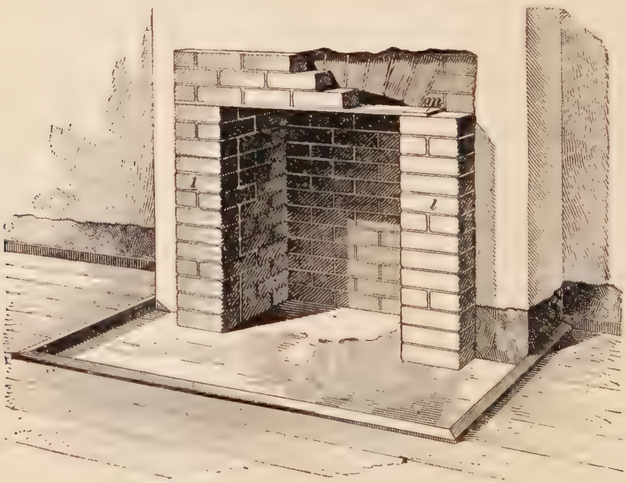
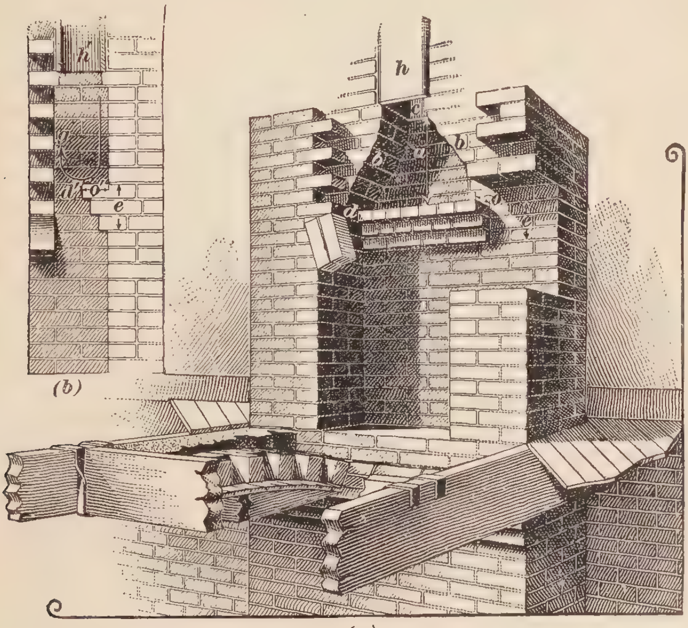


Fig. 10

sufficient to house an ordinary stove, but if a greater depth is

required an additional $4\frac{1}{2}$ inches can be built out as shown at the jambs *l*, *l* in Fig. 10. A flat iron bar *m* is then placed on these jambs, and three or more courses of brick are bedded on the same.

25. In Fig. 11 at (*a*) and (*b*) is shown a fireplace opening such as would be used in Canada and America to accommodate the particular type of grate in use there. The method of contracting the throat of the chimney transversely, just over the



(*a*)

FIG. 11

fireplace, as shown in (*a*) and (*b*) at points *d* and *d′*, respectively, is adopted with a view to preventing the influx of a large volume of cold air over the fire, which tends to form an eddy in the throat of the flue, and thereby causes the smoke and gases to be belched out in waves at the head of the fireplace into the room; this is especially so where there is not a regulating damper over the fire. The contraction may be formed by corbelling out several courses of bricks, as at *e*, so that the width at *d* and *d′* may

be 3 or 4 inches, according to the size of the flue, the contracted area being made about equal to the area of the flue. The ledge shown at *o* and *o′*, formed by the upper course of bricks, also serves as a wind break in the case of down draughts, and diverts the swirling current upwards, as indicated by the arrow *g*.

In order to save corbelling or gathering over of the brickwork, patent flue bases or fireplace lintels are now made and can be obtained at reasonable prices. Besides saving considerable labour, it is claimed that they increase the draught, lessen the danger of smoking, and give the most perfect formation to the mouth of the chimney.

26. Flue Linings.—In Fig. 11, the flue is lined with fireclay linings, as shown at *h* and *h′*. These linings are usually made in 2-foot lengths and should be carried up from the neck of the flue to the lower bed of the chimney coping. The holes in the coping are cut to correspond to the inner dimensions of the linings, so as to prevent the descent of rain-water between the back of the lining and the brickwork.

Flue linings made of unglazed stoneware can be obtained of rectangular section, as shown in Fig. 11 at *h*, but are more usually circular, of various diameters.

The dimensions given refer to the clear inside size or diameter. The thickness of the linings varies from about $\frac{5}{8}$ inch for the smaller to about 1 inch for the larger sizes. A square flue lining, 9 inches by 9 inches, or a circular lining 10 inches in diameter, is the smallest size that should be adopted, and is large enough for ordinary fireplaces.

27. Setting Flue Linings.—The flue linings should not be set in lime mortar, but in Portland cement or fireclay, preferably the latter, for at least a distance of 15 to 20 feet above the fireplace, where the joints are likely to be attacked by the flames. Since the fireclay does not contain any fusible constituents, it is well adapted for the purpose.

Where brick-built flues are used, as is usual in ordinary work, they should be constructed with selected hard-burnt bricks laid in cement mortar, the bed and cross-joints being thoroughly filled with mortar.

28. Pargetting or Rendering.—Chimney flues built either of brick or rubble stonework, unless fireclay linings are used, must have the interior surfaces parged as they are carried up by rendering the inside of the flue with ordinary haired mortar,

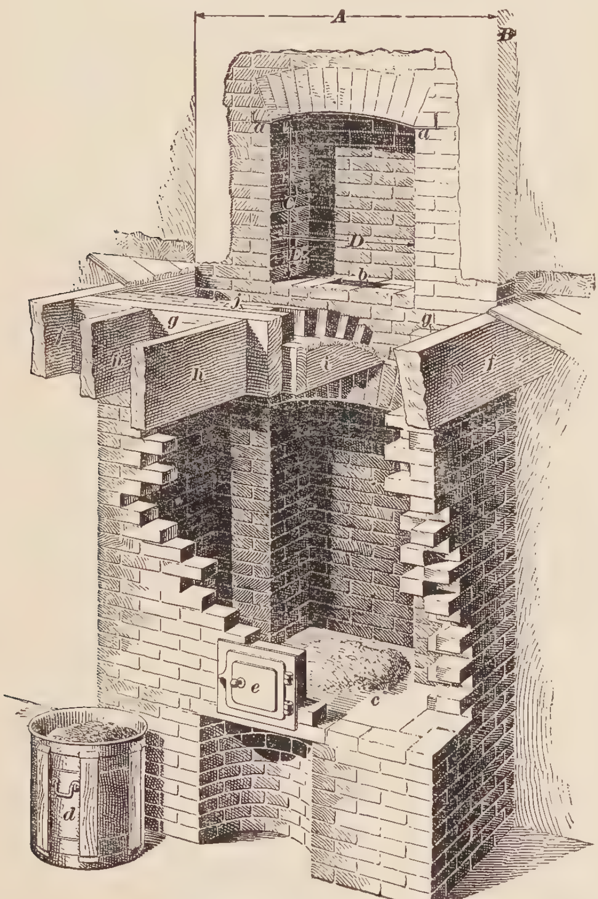


Fig. 12

to prevent the soot lodging on the joints and to provide against the possibility of their not having been flushed with mortar, which would enable the fire to penetrate them. This makes

a tenacious lining, which well resists the heat and is less liable to crack than the ordinary lime mortar.

29. Sweepers.—During the formation of chimney flues, it is well to use a sweeper, which is a bunch of rags, or waste, inserted in the flue, so as to collect the droppings of mortar from the bricklayer's or mason's trowel and prevent them from becoming attached to the sides of the flue. The sweeper is tied together with a strong cord, by which means it may be drawn up as the work progresses.

30. Fireplaces With Ash-Shoots.—In America the fireplace is often constructed with an ash-shoot, by which ashes may be discharged directly into the basement, whence they can be removed periodically. Fig. 12 illustrates this arrangement, which is, of course, adaptable only to certain types of grates. *A* is the chimney breast and *B* the projection of the chimney breast in front of the wall. The fireplace opening is usually about 30 inches in height to the springing, as shown at *C*, and 25 or 26 inches in width at *D*, the depth from front to back *E* being from 12 to 13 inches. These dimensions are customary, but are subject to adjustment to suit special grates and fittings. The arch bar is shown at *a*, *a*. At *b* is shown the ash-flue through which the ashes are discharged into the ash-pit *c*, the floor of which may be kept up 2 feet from the basement floor, and a niche as shown may be formed in the front wall of the ash-pit, allowing the body of the ash-bin *d* to be placed directly under the iron clean-out door *e*, thus facilitating the removal of the ashes. At *f f* are shown the trimming joists of the floor, with the trimmer to the hearth at *g*, receiving the ordinary floor joists *h*, *h*. At *j* is the trimmer arch being built up on the rough centre *i*.

31. In Fig. 13 is shown a view of the fireplace after the tile hearth *a*, the facing tiles *b*, and cast-iron fireplace linings *c*, *c* have been set. The facing tiles, about $\frac{3}{8}$ inch in thickness, may be bedded in plaster of Paris against the rough brickwork, but it is more expeditious to mount them on slate slabs, or slab them direct on cement backing, as shown at *d*, *d*. They can

be attached to the slabs in the workshop, so that they may be set up in one piece on the building.

The sizes of tiling generally kept in stock by the makers are: 6 in. × 6 in., 6 in. × 3 in., 6 in. × 2 in., 6 in. × 1 in., $4\frac{1}{4}$ in. × $4\frac{1}{4}$ in., $4\frac{3}{4}$ in. × $2\frac{1}{8}$ in., $4\frac{1}{4}$ in. × $1\frac{1}{16}$ in. The tiling is glazed and manufactured in various colours, the tint being either uniform or finished with a graduated shade, which gives a certain amount of relief and variety not possessed by a monotone.

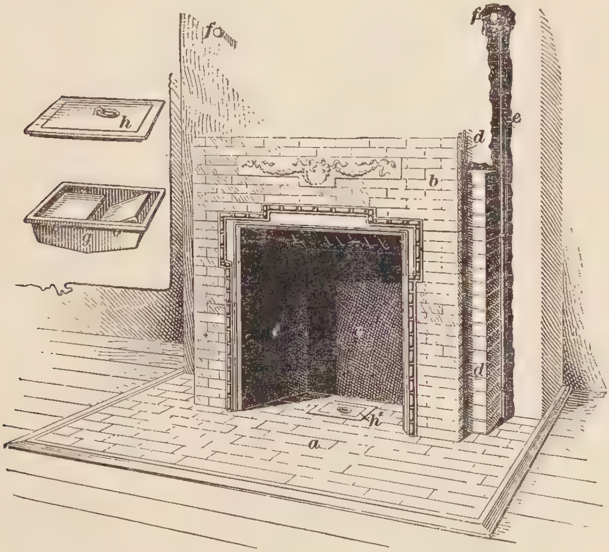


Fig. 13

Mosaic of coloured marbles is also used for the hearth and facing of the fireplace, in which material choice and intricate designs of ornamentation may be executed.

At *e* is shown one of the gas pipes let into the brickwork as it would appear before being covered with the finished plaster, the capped outlets *f*, *f* being set at the accurate height to suit the mantel design.

At *g* is shown the ash-trap, which consists of a cast-iron frame and two pivoted iron shutters that are nicely balanced so that they will drop and allow the ashes to pass through as soon as

they fall from the grate. Ashes accumulating on the hearth beyond the limits of the trap should be swept into it. A brass cover, shown at *h* and *h′*, may be placed over the trap when the grate is not in use.

32. The completed fireplace is shown in Fig. 14, in which a mantel of Renaissance design encases the chimney breast up to the shelf line and forms a framing round the tile facing.

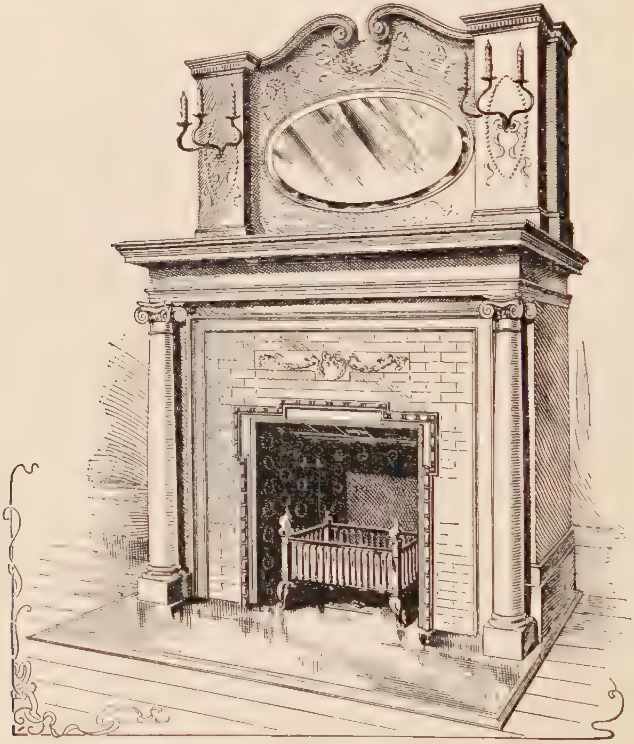


Fig. 14

The outer dimensions of the grate front are usually from 30 inches by 30 inches to 36 inches by 36 inches, the width of its framing being from $1\frac{1}{2}$ to 5 inches, according to the style selected, which thus regulates the height and width of the finished opening. A movable dog or basket grate is shown in

the fireplace opening. Movable dampers in the top lining regulate the draught. The top lining may be fitted with two sets of dampers, one adjacent to the back for direct draught when starting the fire, and one toward the front for use when the fire is under headway.

33. Grates.—For heating the habitable rooms in a building three types of open fire-grate or stove are in general use: the **register grate,** the several forms of **fire-on-the-hearth stoves,** and the **dog,** or **basket, grate,** the two former being most frequently adopted. Ordinary register grates, Fig. 15, consist of a metal frame *a*, generally of cast iron, closing in the fireplace opening and fitted with a receptacle for the fuel, composed of front *b* and bottom *c* furnace bars, and fireclay or metal back and sides *d*, over which, to control the draught and combustion, is arranged an adjustable flap valve, or damper, or a hinged canopy, as shown in Fig. 9 (*c*) at *v*. The most efficient types of metal register grate are combined with a fireclay lining, about 3 inches in thickness, directly surrounding the fire on three sides. A plan and section of a register grate are shown in Fig. 9. In the fire-on-the-hearth stove the fuel is burnt approximately at or below the hearth level, the front furnace bars being replaced by a small lip of fireclay or metal, practically the entire surface of the stove in contact with the fire being formed of fireclay, which is specially shaped. A section through one type of this stove is shown in Fig. 16. The fireclay body *a*, *a* is carefully placed in position in the fireplace recess, and the whole space behind and at the sides is carefully filled with concrete *b* or

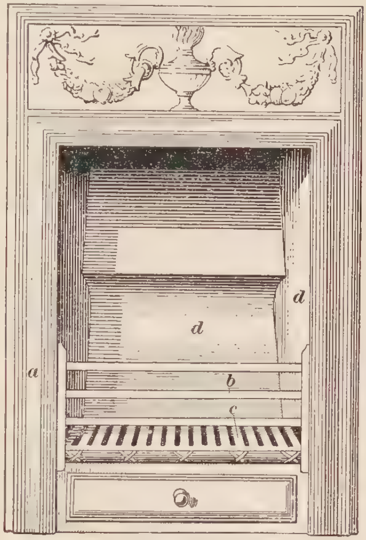


FIG. 15

brickwork, and the top of such filling is splayed and rendered as shown. The top of the raised briquette hearth *c* coincides with the level of the lip on the front of the stove body, and is about 4 inches above the floor line and stopped by the kerb *e*. The covering of the rough chimney breast is here shown carried out in briquettes *d*, which may be coloured and glazed, or a surround of tiles, marble, or other materials may be substituted as shown in section at *f*. The arch over the chimney opening is shown at *g*. The trimmer arch to the hearth is shown at *h* resting on the trimmer *i* and filled in on its extrados with concrete *j*, on which is laid the hearth *c*. Both the register grates and the fire-on-the-hearth stoves are sold in two forms: (1) as fireplace interiors, in which case they are fixed in connection with a separate chimneypiece; or (2) as combined mantel register grates or stoves, in which the entire fitting is in one piece or assembled. The **dog, or basket, grate** shown in Fig. 14 consists of a fuel container, which is mounted on legs, forming a raised fire-basket, which, being portable, requires no setting, being simply placed within the fireplace recess.

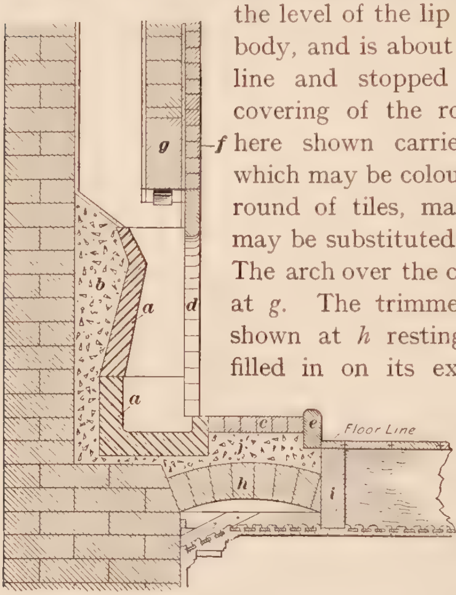


Fig. 16

34. Arrangement and Setting of Kitchen Range.—The arrangement and setting of a kitchen range are illustrated in Fig. 17 and Fig. 18 (*a*), (*b*), (*c*), and (*d*). The range shown in Fig. 17 consists of a fire *a* with a high-pressure boiler *b*, Fig. 18, of the "boot" pattern at the back of it; roasting and baking ovens *c*, *c*; hot plate *d*, *d*; and plate rack *e*. The heat of the fire can be concentrated upon each oven or upon the boiler by an arrangement of horizontal and vertical flues *f*, *f*, controlled by dampers *g*, *g*, or the fire may be converted from a close into

an open fire by sliding back the top plate *p* and drawing out the hinged canopy *h* and side checks to support the same. Combustion is controlled by means of an adjustable fire-bottom, as shown at *a* in Fig. 18 (*c*), which can be raised or lowered according to the size of fire wanted. The direction of the heated air from the fire *a* round the ovens and boiler is shown by the arrows in

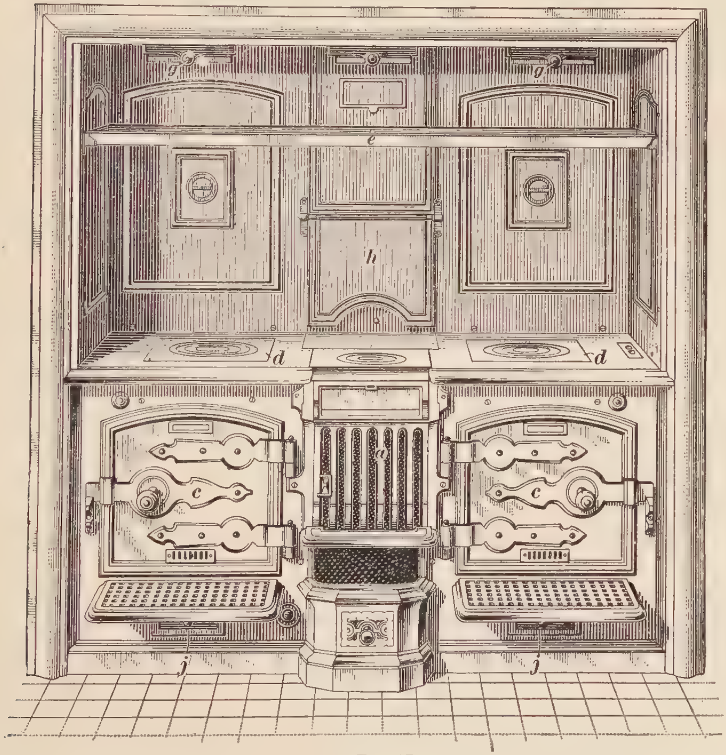


Fig. 17

Fig. 18 (*a*), (*b*), (*c*), and (*d*). In (*c*) the hood *h* is shown open as it would be were an open fire wanted, and either the top plate *p* could be pushed back so as to form an open fire or one or two of the rings forming the top plate could be lifted out, when the smoke from the fire would be caught by the hood *h* and pass into the flue instead of passing under the boiler at *n* as it would do were the hood and top plate closed.

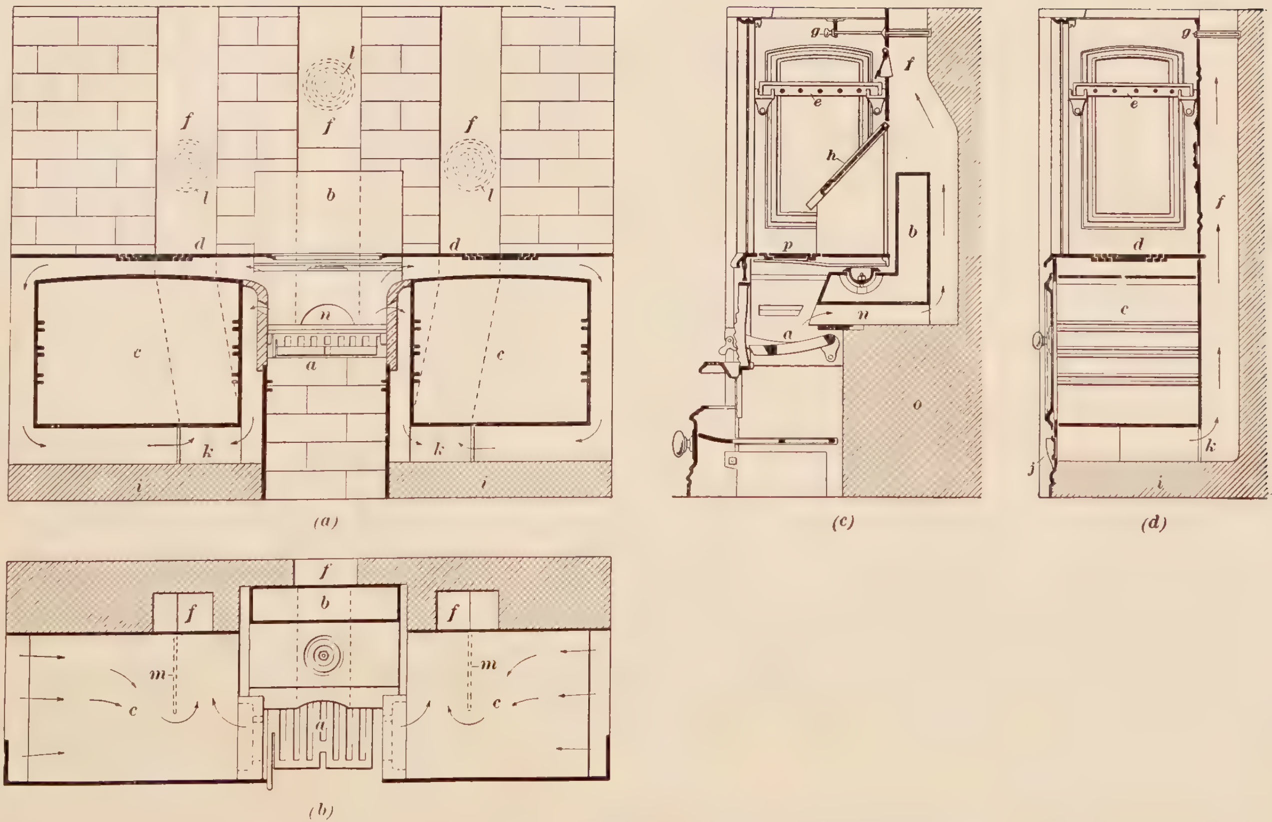


FIG. 18

35. In setting the range a solid brick horizontal lining *i*, *i*, as shown in Fig. 18 (*a*) and (*d*), grouted with fireclay or fire-cement, is built upon the floor of the fireplace recess, under the ovens. This lining is generally about $4\frac{1}{2}$ inches high, but varies with different patterns of kitchen range, and the height must be determined by the level of the soot door *j* upon the range front shown in Fig. 17. A similar lining is built vertically at the back of the recess, and flues *f*, *f* are formed in the same, two to suit the outlets *k*, *k* adjoining the baffle plates *m* under the ovens, and one continuing the arched opening *n* under the boiler. The seating for the boiler is of solid brickwork *o* built up from the floor. Soot doors *l*, *l* are provided in the covings, or lining, of the range for access to the flues, which require frequent sweeping. The baffle plates *m* are inserted to break the flow of hot air under the ovens and prevent it going directly up the flue *f* before circulating under and warming the oven. The approximate direction of the air-currents from the fire is shown by the arrows in Fig. 18. This type of kitchen range is one of many, but the setting is very similar in all cases, and if any difficulty is experienced in setting the range, the makers are generally willing to give full instructions on the subject.

SETTLEMENT IN BRICKWORK

36. The settlement that occurs in brickwork is due to the shrinkage of the lime in the mortar joints as they dry out. This settlement is practically proportional to the number and thickness of the joints in the wall. Therefore, if the walls in a building are of a uniform height, they will shrink evenly, no matter how many windows and doors there may be in the structure.

There is another cause, however, that is not so easy to deal with. In this case, the shrinkage is caused by the settling of the joints due to the weight of the brickwork above. The more weight there is on a certain joint, the more the brickwork will shrink. Fig. 19 (*a*) represents a tall tower with a window opening in it. At (*b*) is shown a section through the tower on the line *a b*. Consider the tower to be divided by the line *f g*;

then, an equal weight of brick will bear on each side of this line. Because of the bearing area taken out by the window in the part *d*, however, there is less area to support the weight than there is at part *e*. Therefore, the pressure per square inch on the brickwork at *d* will be greater than the pressure per square inch on that at *e*, and the joints in the part *d* will compress more than the joints in the part *e*; consequently, the tower will settle unevenly and be out of plumb.

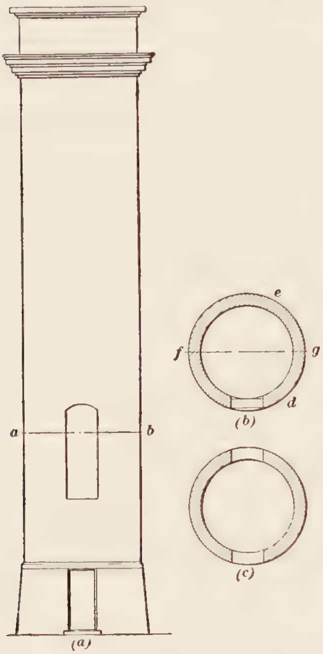


FIG. 19

37. In building a tower where it is desired to put in a window, two openings opposite each other are usually left in the shaft, as shown at (*c*). This method divides the load evenly on both sides of the opening, and allows the tower to settle uniformly throughout. Afterwards, if only one opening is required, the other one may be bricked up.

Of course, the amount of shrinkage is not always large except in a tall narrow building with a large opening in it, as, for instance, the flue opening in a brick chimney stack, but nevertheless the shrinkage is sometimes enough to cause trouble, if precautions are not taken to prevent it.

38. There is another difficulty about placing an opening in a circular shaft, that is, the arch above the opening has no walling in its line of action to take up its kick, or thrust. For this reason, the brickwork above an opening in a tower should be supported by a steel beam embedded in the work. Afterwards, an arch may be sprung in below the beam, but this arch is simply placed there for appearance, and the entire load should be carried on the beam.

ORNAMENTAL BRICKWORK

DESIGN IN BRICKWORK

METHODS OF ORNAMENTATION

39. There are numerous methods of ornamentation in brickwork which have been used with great success in old examples in certain districts lacking a supply of stone or subject to other influences. In such districts a highly developed brick architecture may be studied, and certain principles of design may be utilized in the production of good modern brickwork. Generally, the difference between various types of brickwork may be resolved into a limited number of principles ; these are : (1) variation in the colour of the bricks or the jointing material ; (2) variation in the texture of the bricks or the character of the jointing, the latter producing texture in the work when built ; (3) variation in the kind of bond used in laying the bricks ; (4) variation in the shape of the bricks ; and (5) the employment of such constructive features as pilasters, string-courses, plinths, arches, niches, cornices, etc. These methods can be used in combination.

40. Use of Coloured Bricks.—The colour of the bricks is of course a matter of great importance and wide scope, being governed to some extent by particular requirements or considerations of local supply, and, apart from these considerations, is a question of taste or judgment especially within the province of the architect. In addition to the great range of variation in colour and combinations of colours of the actual bricks to be used, there are two general methods of controlling the effect. One is by a great mass of solid colour, and the other is by making each brick appear separate and distinct. In the first case the

mortar is made the same colour as the bricks, while in the second case the mortar is made to contrast, usually being a lighter, but sometimes a darker, shade than the bricks. In using light-coloured mortar the joints in the face of the wall are often made as wide as $\frac{3}{4}$ inch, in order to make the bricks stand out. In this case, as a rule, the face of the wall is not calculated to have much strength ; therefore, the backing must be made strong enough to carry the load. Rough bricks always look more smooth when pointed with mortar of their own colour.

41. Fig. 20 represents a portion of a wall built in different coloured bricks. This arrangement can be greatly varied in

Fig. 20

colour and design. The darker bricks in the illustration are enamelled, or vitrified. They can be procured with the enamel burnt into any side or end. The illustration is that of an ornamental frieze, but this kind of work may be used in many other places on a building, as will readily suggest themselves to the designer.

42. The spaces between the dark-coloured bands may be finished in the form of sunken panels, and, after the wall is finished, the panels may be filled up with plaster of the desired shade, which is usually lighter in colour than the surrounding bricks. This style of colour ornament is cheaper than using enamelled bricks, although perhaps not so durable. The plaster filling is

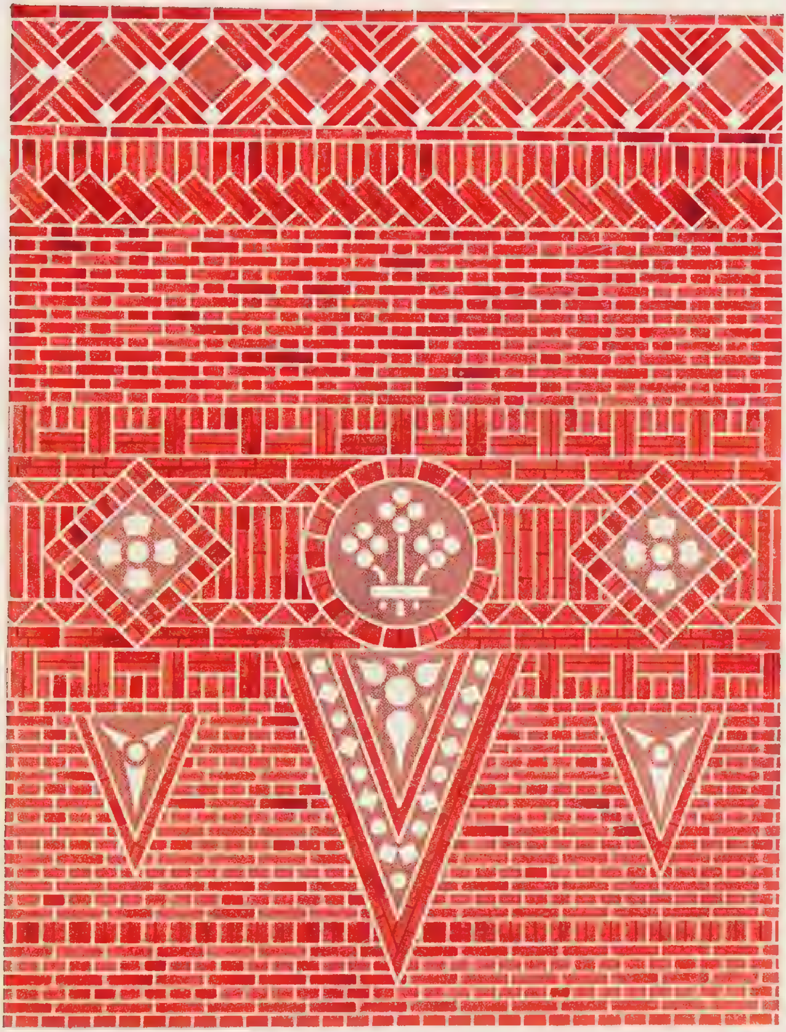


FIG. 21

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FIG. 32

not always brought out flush with the brickwork, but is sometimes left a little sunken to get the effect of the shadow on it.

The arrangement shown in Fig. 20 shows the outer facing of brickwork laid entirely as stretchers. This method is sometimes used on the ground of economy, or in hollow walling, where the outer shell is only $4\frac{1}{2}$ inches thick. Elsewhere it is of course better construction to bond the facing brickwork in the usual manner with English or Flemish bond.

43. Another method of ornamentation in colour is shown in Fig. 21. The light-coloured pieces are made in different shades of marble. In some work, tiles or faience are used instead of marble, and the designs are either painted or burnt thereon. In work of this kind any slight variation in shade in the colour of the bricks adds greatly to the attractiveness of the building.

44. Much of the beautiful quality of old brickwork is produced by the texture of the bricks, which are rough and uneven, either from age and weathering or from primitive methods of manufacture. Objection may be taken to the irregular surfaces and shapes, upon practical grounds, but the facts that such brickwork has resisted some centuries of wear, and has the advantage of weathering and mellowing rapidly, are considerations which may be given precedence for certain situations, providing the clay from which the brick is made is durable. Where a hard, dense, machine-made brick must be used, an effect of texture may be produced in the work by forming a deeply recessed joint in the mortar. Good material should be used throughout, and judgment must be exercised before this method is adopted.

The use of fine rubbed brickwork with very thin joints, which in some examples are almost imperceptible, was introduced into England, and very highly developed by Sir Christopher Wren, in the reign of Charles II. Fig. 22 illustrates an example, later in date, of the Orangery, or Banqueting Hall, in the gardens of Kensington Palace. Such brickwork, of extreme regularity and fineness, is called gauged work, and is formed of special bricks called rubbers, the jointing material being of pure slaked lime, known as putty, or a mixture of dried white lead and liquid shellac.

45. Ornamentation in bond is sometimes accentuated by the colour of the mortar joints, by raised work, or by the colour of the bricks themselves. Variation in bond is usually shown in string-courses and similar details in different-coloured or moulded bricks.

An illustration of a quaint Dutch gable is shown in Fig. 23. Here the ornamental effect is obtained by a variation in the

Fig. 23

bond. The bricks along the sides of the gable are set at an angle with their ends normal to the roof line, while the remainder of the work is in Flemish bond. One advantage of this gable construction is that no bricks have to be cut to thin tapering

edges on the sloping line of the gable. At *a, a* will be seen anchors to tie-rods that hold the gable in place. These anchors also add to the artistic appearance of the structure.

46. Irregular-Shaped Bricks.—Bricks are manufactured in a variety of shapes. In addition to those of ordinary dimensions, four courses of which are 1 foot in height, special narrow bricks are stocked, or made to order, by certain manufacturers; a

FIG. 24

course of these bricks is sometimes 1 inch, $1\frac{1}{2}$ inches, or more frequently 2 inches in height. A modern American example of the use of these special-shaped bricks is given in Fig. 24.

Of special irregular-shaped bricks, the most usual are cants, squints, birdsmouths, external and internal angles, arch-bricks and keys, and bullnoses, the latter being single or double and of various radii.

Moulded bricks are to be obtained in an immense variety of sections, with the necessary special bricks to match, for the mitres, stop ends, etc. These are used for cornices, strings, plinths, sills, jambs, panels, and similar situations, and may be plain moulded or enriched.

CONSTRUCTIVE AND DECORATIVE FEATURES

BRICK COLUMNS, PILASTERS, AND RUSTICATION

47. An example of a brick capital and base to a brick column is given in Fig. 25. These are formed entirely in moulded bricks of ordinary patterns, and illustrate their applicability, when suitably combined, to the formation of architectural features. Fig. 22 shows the application of brickwork to the shafts of some engaged columns and pilasters, in which an occasional joint is emphasized by being recessed; by this means, the brickwork is separated into masses larger than the general element, and an appearance of greater scale is contributed. A similar treatment is to be observed in the larger arched openings in both façades.

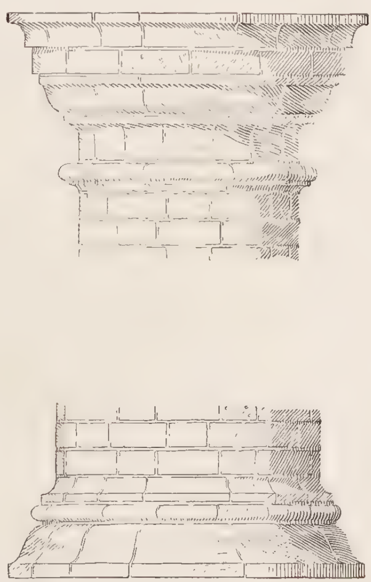


Fig. 25

48. Fig. 26 is a view of a part of the Grammar School at Rye, Sussex; it is a striking example of brick architecture, in which the entire facade is constructed of that material. The architectural order, as exemplified in the pilasters and cornice, is not, it is true, strictly orthodox, according to the classical standards, but the designer has achieved a skilful adaptation to

Fig. 26

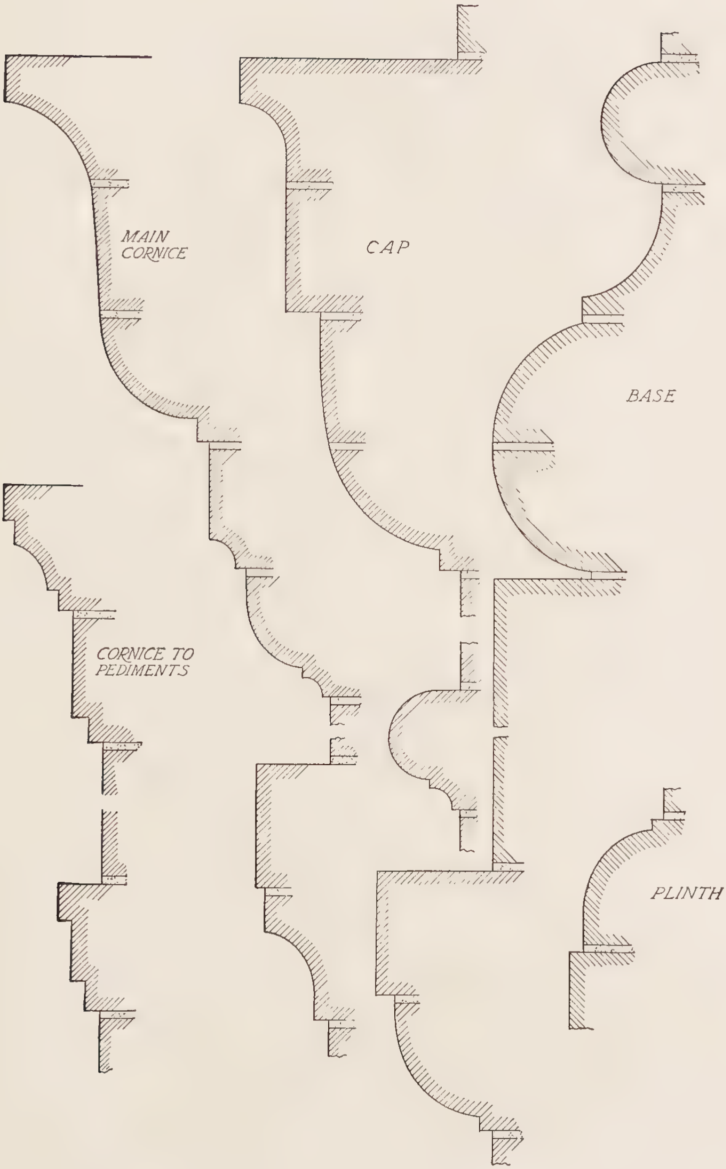
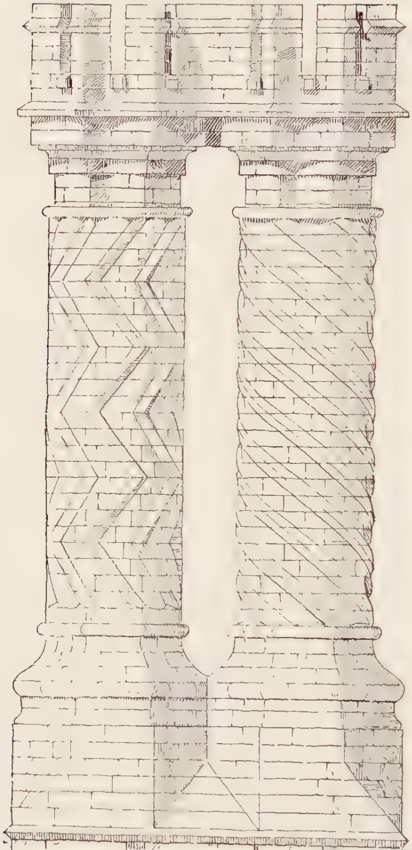
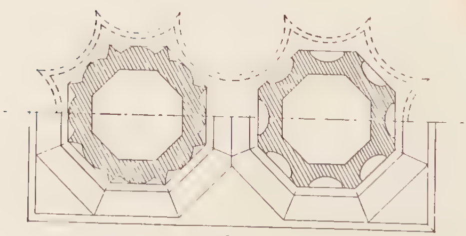


FIG. 27



(a)



(b)

Fig. 28

the material, and sketch details of the mouldings, illustrated in Fig. 27, are not without interest.

49. Chimney shafts form one of the most ornamental features of the latter part of the fifteenth and beginning of the sixteenth centuries. English domestic architecture of that period furnishes many magnificent examples of the use of brick, in single and clustered shafts of great beauty. Fig. 28 illustrates an example from Hampton Court Palace, which is typical of a great number still existing. At (*a*) is shown the elevation of two chimneys designed as one stack, while at (*b*) is shown a sectional plan of same.

STRING-COURSES

50. Moulded bricks are generally used in raised work. The architect is not necessarily governed by the bricks carried in stock, but may order any shape that is desired, but it is cheaper and quicker to use some standard shape that is kept on hand at all times by the manufacturer or dealer.

The projection of the bricks in mouldings, string-courses, etc., should be as small as possible to carry out the design, in order that the bricks may bond back into the wall. If the projection is too great, there is danger of the bricks falling out.

When practicable, and the projection is not too great, it is better to use more stretchers than headers in a string-course, because it takes a less number of stretchers than headers to run a given number of feet, and the cost of the bricks is therefore less, but heading courses are considered better construction.

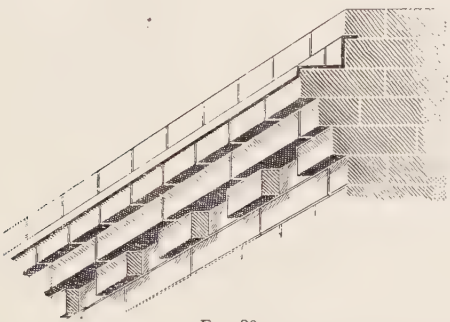


Fig. 29

51. Fig. 29 shows the best method of protecting the top bricks of string-courses or cornices from the weather. This is done by means of strips of sheet lead, which are built

into the second joint above the top course and turned down slightly over the face.

When it is not possible to use sheet lead to protect the projecting bricks of the top course, some other means should be

Fig. 30

adopted, for, unless some precaution is taken, rain-water and frost will eventually destroy the mortar joints and allow water to penetrate into the wall.

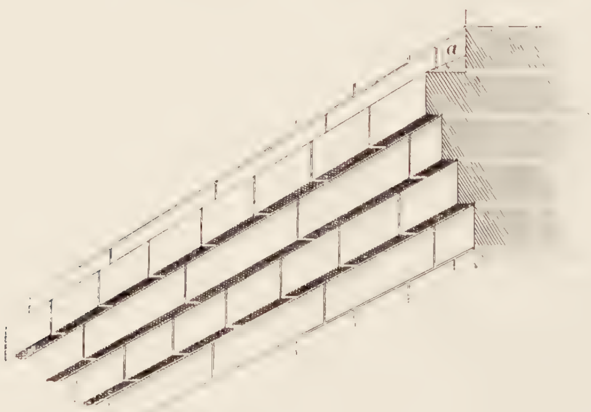


Fig. 31

52. A string-course of chamfered and moulded bricks is shown in Fig. 30, where *a* shows the chamfered bricks on top

of the cornice or string-course, with the moulded bricks under the top course. The top course *a* should be laid as a stretcher course, provided that it does not project more than 3 inches from the face of the wall; this reduces the number of end joints in the brickwork. The bricks should be laid in cement, so that the mortar in the joints will not be washed out. If the top course *a* is built as a stretcher course, the moulded course under it should be a heading course.

53. Another way of protecting a string-course consists in laying a weathering of Portland cement, as shown at *a*, Fig. 31. This method is not considered so good as the other methods described, since the cement may become cracked and eventually fall off.

CORNICES

54. In buildings with flat roofs or balustrades the walls are often finished off with cornices of brick, terra-cotta, or stone.

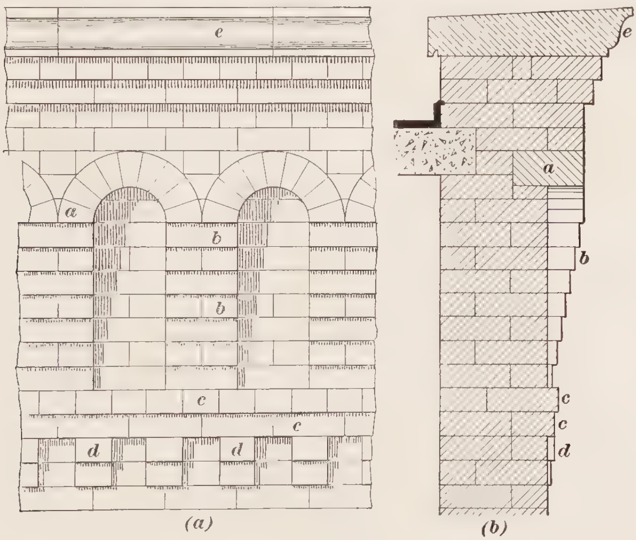


Fig. 32

Where any considerable amount of projection is required, the best plan, especially in brickwork, is to adopt some corbel treatment,

building the cornice up by slightly projecting each course. This mode of constructing brick cornices is shown in Figs. 32 and 33.

55. Fig. 32 shows an arched and dentilled cornice, which is very effective in high buildings where a good shadow effect is desired without great projection. The cornice is shown in elevation at (*a*) and in section at (*b*). At *a* are shown the $4\frac{1}{2}$-inch arches, which are made of bricks laid the $4\frac{1}{2}$-inch way and sprung between the corbels. For very special work, these bricks should be gauged, or rubbed, so that they will fit exactly in the arch. At *b* are shown the brick corbels, which are made 9 inches, or one brick wide and seven courses high, each course having a projection of slightly over $\frac{1}{2}$ inch beyond the course immediately below it; *c* shows the string-course, composed of two courses of bricks, on which the corbels stop, the upper course projecting $\frac{1}{2}$ inch; *d* is a dentil course of bricks laid as headers, with a $4\frac{1}{2}$-inch space between each dentil, which is two courses in height, each course projecting $\frac{1}{2}$ inch; and *e* shows a moulded, weathered, and throated stone coping finish to the top of a wall.

56. In Fig. 33 is shown a less elaborate and cheaper brick cornice. The elevation is shown at (*a*) and the section at (*b*).

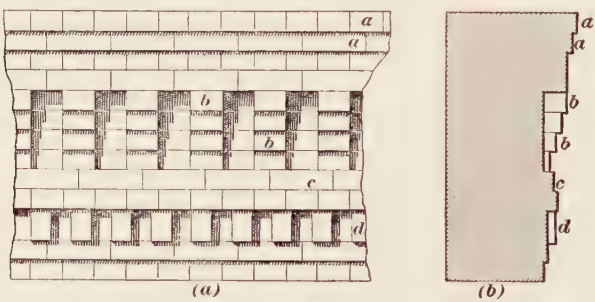


FIG. 33

The crown course *a*, *a* is composed of two courses of bricks, each projecting $\frac{1}{2}$ inch. The corbels *b*, *b* are each $4\frac{1}{2}$ inches, or one-half brick, wide, and are spaced $4\frac{1}{2}$ inches apart; three of the courses in each corbel project about $\frac{3}{4}$ inch each, making the whole projection about $2\frac{1}{4}$ inches. At *c* is shown the string-course on which the corbels stop, laid in two courses of bricks, the lower course

having a projection of $1\frac{1}{4}$ inches and the upper course setting back $\frac{1}{2}$ inch from the face of the lower course. At *d* is shown the dentil course of bricks set on edge, having a space between each dentil of $2\frac{1}{4}$ inches and projecting 1 inch. The top of the string-course *c* should be protected from the weather by sheet lead, as shown in Fig. 29, or by Portland cement, as shown in Fig. 31.

57. A very effective brick cornice, especially for buildings of medium height, is shown in Fig. 34. This cornice bonds well, gives a strong shadow, and is easily laid. At *a* are shown the two top courses of brickwork in the cornice; the lower course is laid as stretchers, the upper course as headers projecting $\frac{1}{2}$ inch

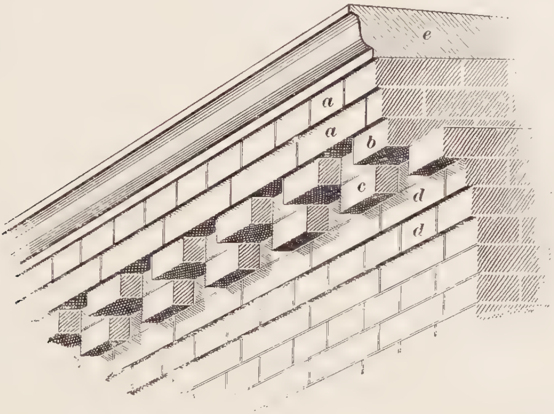


Fig. 34

over the lower, and the lower course $\frac{1}{2}$ inch over the dentil course. At *b* is shown the upper dentil course, projecting $1\frac{1}{2}$ inches over the lower dentil course; *c* is the lower dentil course, projecting 2 inches beyond the lower string-course; *d* is the lower string-course of two courses of bricks, each one projecting $\frac{1}{2}$ inch; and at *e* is shown the moulded and weathered stone coping.

CLEANING AND PROTECTING BRICKWORK

58. After a building constructed of pressed bricks is finished and pointed, it should have its walls cleaned down. Any mortar that has adhered to the walls may be easily removed with a

stiff scrubbing brush. To take out mortar stains, the walls are washed with dilute hydrochloric acid in the proportion of about 1 part of acid to 20 parts of water.

EFFLORESCENCE

59. Very often, on buildings of stone or brick, more particularly the latter, white stains will appear on the surface of the walls after a few days of wet weather. These stains are called **efflorescence,** and are due to one or more of the following causes: (1) The water used in making the mortar dissolves salts of potash or soda from the bricks or stone, and when the water evaporates these salts are deposited on the surface of the wall; (2) the soda in the bricks is drawn out by capillary attraction; (3) the clay in the bricks contains iron pyrites or else is burnt with sulphurous coal, thus forming sulphuric acid, which combines with the magnesia in the lime to form a white salt; (4) the clay of which the bricks are made sometimes contains soluble salts, which are dissolved by rains and deposited on the surface of the brickwork.

60. This discoloration can be prevented if boiled linseed oil is applied to the wall every 3 to 5 years in the same manner as paint is applied with a brush, and efflorescence can be removed by washing the walls with dilute muriatic or nitric acid. A well-known authority has recommended as a preventive that to every barrel of cement used in making mortar should be added 100 pounds of quicklime and 10 pounds of animal fat. This last method does not always prevent efflorescence, but merely makes it less noticeable; it is seldom used to-day, although it was at one time employed to some extent.

WATERPROOFING BRICKWORK

61. After a driving rain or a sleet storm, a wall even as thick as $13\frac{1}{2}$ inches may be wet through. It is therefore not desirable, in the very best work, to plaster directly on the walls, as the plaster and the wallpaper may be spoilt; if, however, the wall

is plastered directly on to the brick, it can be made waterproof, or built hollow, or the wall can be furred with 2″ × 1″ furring strips, to which the lath and plaster is attached, though the last method does not prevent the moisture coming through the wall itself, and is open to the objections previously stated.

62. Waterproofing.—There are two methods of waterproofing brickwork. The first is to paint it with oil colours, and the second is to coat it with hot asphalt. Either method, of course, will spoil all the beauty of the bricks, and is not to be recommended except in extreme cases. If either of these methods is adopted, however, the wall should be thoroughly dry before the application. If asphalt is used, it should be put on while hot.

A few coats of boiled linseed oil will usually keep out moisture for 2 or 3 years, and will not injure the colour of the bricks.

63. Processes of Waterproofing.—There are several good methods of waterproofing a wall which also prevent efflorescence. In one process the wall is coated with two solutions. First, a solution of Castile soap in water is applied while boiling hot, care being taken that it does not froth. After this coat has become thoroughly dry, a coat of alum and water at an ordinary temperature is put on. These coats, applied in the manner just described, form an insoluble compound, which enters the pores of the bricks and makes the wall waterproof. In extreme cases it may be necessary to repeat this process, but usually one coat of each will suffice.

There are also several patent waterproofing compounds on the market. Probably the best two of these are Duresco and Szerelmy's Solution, both of which can be obtained in transparent liquid form and consist principally of a solution of silicate of soda.

TERRA-COTTA, FAIENCE, AND TILING

TERRA-COTTA

VALUE IN CONSTRUCTION

1. The uses of **terra-cotta** in architectural work are so varied and extensive as to be almost endless. Both for inside and outside decorative and plain work it forms a very important substitute for stone and brick, especially in positions exposed to the weather. Its great value for building purposes consists in its durability. If made of the right kind of materials and properly burnt and vitrified, it is practically impervious to moisture, and hence is not injured by frost, which is such a powerful destructive agent to many building stones. Atmospheric gases likewise have no effect on well-burnt terra-cotta, and though dirt will gather on the surface of terra-cotta in a town atmosphere, it may be washed down periodically and rendered as clean as on the day it was erected. In many parts of Europe are to be seen examples of terra-cotta that have endured the changes of the weather for hundreds of years and yet remain in good condition, while stone similarly exposed has become more or less disintegrated. Another point of value is that it affords no lodgment for vegetable growths, as do some stones. When terra-cotta is not sufficiently burnt, it lacks the proper surface vitrification, and is then to some extent absorbent, and consequently not so durable. The heat-resisting power of terra-cotta is also of importance, making it a very desirable

material for use in fire-resisting buildings. This has been abundantly demonstrated in several great fires.

2. **Economical Advantages.**—The cost of terra-cotta varies according to the size and amount of work required. For plain work the cost will be not much less than for stone. When, however, many pieces of the same size and shape are required, terra-cotta is frequently much cheaper than stone; and when there are many moulded and decorative features which would necessitate much hand work for dressing and carving if stone were employed, the advantage of using terra-cotta in point of cost is evident. Further economy may be obtained by repeating judiciously the detail of the ornamental features, so as to require the fewest possible different pieces. Another advantage is that hollow terra-cotta blocks weigh less than stone, and, consequently, when the former is extensively used, the saving in cost of transportation, in certain districts, may be an important item.

MANUFACTURE OF TERRA-COTTA

3. The material in terra-cotta is practically the same as that in bricks, but a much better quality of clay must be used, a good fireclay being the best of all. The method of manufacture also is different from that of bricks. The proper selection of the materials used requires considerable skill and knowledge of effects to secure desired results; unsuitable clays are highly unsatisfactory on account of their liability to crack and warp during drying and burning. The clays used are obtained from different places and must be mixed in proper proportions in order to obtain certain results. Much artistic skill is necessary to produce the elaborately decorated work now so common; consequently, terra-cotta manufacture ranks much higher than brickmaking.

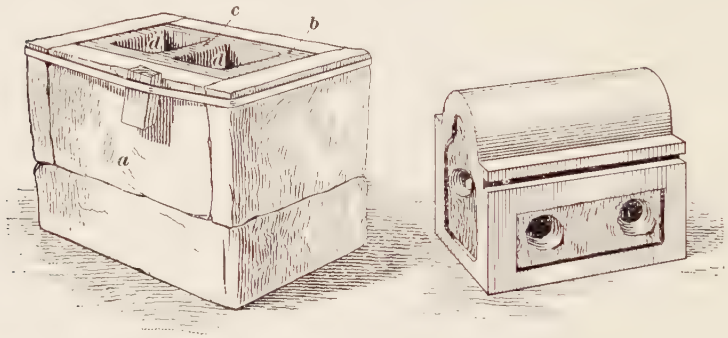
4. After the clay is mined, it should be seasoned by being exposed to the air for some time. It is then ground and mixed with water and materials known as *grog*, which, in burning, reduce shrinkage and produce a partial vitrification, thereby increasing

the durability of the terra-cotta. Grog usually consists of fine sand, pulverized brick, or burnt clay, and prevents, to a great extent, cracking and warping, by controlling the shrinkage. The mixture is then thoroughly incorporated by various mechanical processes, and is formed into cakes of convenient size for the subsequent operation of moulding.

5. **Shrinkage-Scale, or Clay-Size, Drawings.**—All clays contract to some extent during drying and burning; allowance must therefore be made for this contraction in the very first stage. For this purpose the true-scale drawings of the parts of a building to be executed in terra-cotta require translation into what are called **shrinkage-scale**, or **clay-size, drawings**, which are full size plus a due allowance for the amount of contraction, which varies according to the nature of the clay. These clay-size drawings are prepared by the architect or the manufacturer, as arranged, but more frequently by the latter, who can usually be trusted to follow the originals faithfully in redrawing. The clay-size drawings when checked are passed on to the model maker.

6. **Models and Moulds.**—If only a single piece is wanted, the clay is modelled directly into the required shape, no moulds being used. When, however, numerous pieces of the same size and shape are to be moulded, a full-size model of plaster and clay is made, from which a plaster cast is taken; this is thoroughly dried before being used. The mould is then passed on to the presser, by whom the tempered clay is compacted into and round the surfaces of the mould by hand, with sufficient force to take a perfect impression of its form, at the same time forming a hollow block or shell of clay of uniform thickness. This hollow block is braced by cross-partitions of clay, varying from $1\frac{1}{4}$ inches to 2 inches in thickness, and not more than 6 inches apart. The clay in the mould is then allowed to become partially dry. Fig. 1 (*a*) shows a clay block in the mould, while (*b*) shows the block after it is taken out; *a*, is the plaster mould; *b*, the clay block face down in the mould; *c*, the web of clay; *d*, the cells formed in the block in moulding. When taken out, the block is sent to the carver or modeller if it requires decoration, or to the clay finisher if it merely needs *touching up*, or trimming. The unburnt terra-cotta

is next removed to the drying floor, which is kept at a temperature of between 70° and 80° F., and is thoroughly dried. It is then ready for the kiln, in which it remains for several days for burning



(a) (b)

Fig. 1

and cooling. In the burning of certain clay mixtures, an efflorescence is formed, which, on cooling, becomes hard and vitrified, rendering the material more durable ; this glaze should not be broken, or the durability of the block will be impaired.

7. **Colour.**—Owing to the improvements in methods of manufacture, terra-cotta may now be had in almost any shade, from nearly pure white to a deep red ; but previous to about 25 years ago, most of the terra-cotta produced was red or buff. The colours most commonly used at present are red, buff, pink, tawny, and grey. Other colours may be produced by chemical means, but a better quality of material is likely to result if those colours are used that are natural to the clay, and which do not require overburning or underburning of the clay to produce the desired effect

8. **Varieties of Terra-Cotta.**—Terra-cotta is manufactured chiefly in three varieties. The **ordinary** has a plain unglazed surface and is more or less porous; while the surface of the **vitreous** is covered with a slight vitreous glaze, rendering it thoroughly impervious to moisture and proof against atmospheric

action even in manufacturing towns. The third variety consists of the special **full-glazed,** or **matt-glazed, terra-cottas** which have been classed under the heading of faience.

CONSTRUCTION DETAILS

9. Size of Pieces.—In designing and preparing details for terra-cotta work, care should be exercised to limit the size of the pieces to the most practical and economical dimensions. It is well to keep the size of the blocks down to 1 foot cube wherever possible, for, while very much larger blocks can be made, they are exceedingly liable to accident in drying and burning, with ensuing delay. Besides, such sizes are very costly, as great skill and care are necessary in their manufacture to prevent warping. All the work should be divided into as many pieces as possible, care being taken to ensure proper bonding. Short lengths are more easily handled and less liable to defects in manufacture and breakage than long ones. When brick structures are dressed or faced with terra-cotta, it is essential that the pieces be multiples of the same dimensions as the brickwork, in order that they may be bonded properly into it without cutting.

10. As considerable time is expended in the many processes involved in manufacturing architectural terra-cotta, the working drawings should be sent to the manufacturer at least 2 months before any portion of the terra-cotta is needed, so as to allow ample time for manufacture and delivery. These drawings should consist of $\frac{1}{8}$-inch or $\frac{1}{4}$-inch scale plans, sections, and elevations, $\frac{1}{2}$-inch scale details, all fully dimensioned, and full-size sections of the mouldings. If the building is of steel construction, it is important to include drawings of the steelwork wherever the terra-cotta is affected. It is also necessary to give exact dimensions of the brick courses, so that the terra-cotta may be jointed to bond with the brickwork. While small pieces may often be obtained in less time, it is not advisable to force the work, as it increases the cost greatly and, besides, prevents the exercise of proper care during manufacture.

11. Weight and Strength.—Solid blocks of terra-cotta will weigh about 120 pounds to the cubic foot. Hollow pieces with webs $1\frac{1}{2}$ inches thick will weigh from 65 to 85 pounds per cubic foot, small pieces being heavier per cubic foot than large ones. An average weight for hollow blocks is from 60 to 70 pounds per cubic foot. Authorities give the safe working strength of terra-cotta blocks in the wall at about 5 tons per square foot when unfilled, and 10 tons per square foot when properly filled solid with concrete.

12. Filling, Setting, and Pointing.—Before using, each piece of terra-cotta should be carefully inspected. Abutting surfaces should match perfectly and each piece should fit exactly in its proper place. Terra-cotta should give out a clear, metallic sound when tapped with a hammer, and a fracture should show a close and homogeneous texture and reasonably uniform colour. The surface should be hard enough to resist a knife scratch. Pieces that are broken or twisted or have the surface chipped in any way after burning should not be used. The cavities formed in the blocks should be filled before setting with fine concrete, composed of 1 part of Portland cement to 7 parts of clean river gravel, broken brick, or stone, sufficiently small to pass through a screen of 1-inch mesh. Roman or other non-swelling cement is sometimes recommended in place of Portland cement, but the latter is suitable if not used in excessive proportion. The use of coke breeze for the aggregate is often deprecated, owing to the presence of sulphur, and blocks filled with breeze have frequently been found to burst owing to expansion of the material. The terra-cotta should be solidly built into or firmly anchored to the walls, and in all blocks subject to compression the voids should be filled to make the work as strong as possible. The mortar used in setting terra-cotta should be composed of Portland cement and sand, mixed in about the proportion of 1 to 2. The method of laying the blocks is similar to that of setting stone, and is generally done by the bricklayer, the terra-cotta work being carried up simultaneously with the brickwork. In some cases, immediately after the pieces are set, the face joints are cleaned out at least $\frac{3}{4}$ inch in depth,

to make ready for pointing. More frequently, however, the pointing is done with a deep weather joint as the work proceeds. The pointing mortar should be made of about 1 part each of Portland cement and clean sharp sand, which is sometimes coloured to correspond with the terra-cotta.

13. Terra-Cotta Window Dressings.—Window openings should not be spanned by single pieces of terra-cotta. Sills are usually formed of blocks not over 2 feet long, and should preferably be less, and the height of the pieces composing the joints should not be more than 12 inches. Fig. 2 shows a terra-cotta sill which is sunk and weathered on top, moulded in front, and

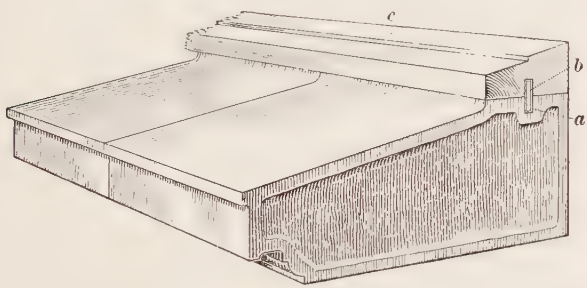


Fig. 2

grooved at *a* for the reception of a galvanized-iron water bar *b*, which would also be let in to the wood sill *c*.

14. Terra-Cotta Doorway.—Fig. 3 represents a good example for terra-cotta work, showing the type of detail and the accuracy and neatness with which suitable pieces may be manufactured and laid. The figure represents a doorway, *a*, *a* being the architrave, with a corresponding depth of return within the opening, and *b* the lintel, which is formed of several pieces which are jointed as shown at *c*, *c*.

15. Terra-Cotta Cornices.—Terra-cotta is extensively used for the cornices of buildings, as it is much lighter and usually cheaper than stone, especially if the work requires elaborate decoration. In order to balance a stone cornice during erection,

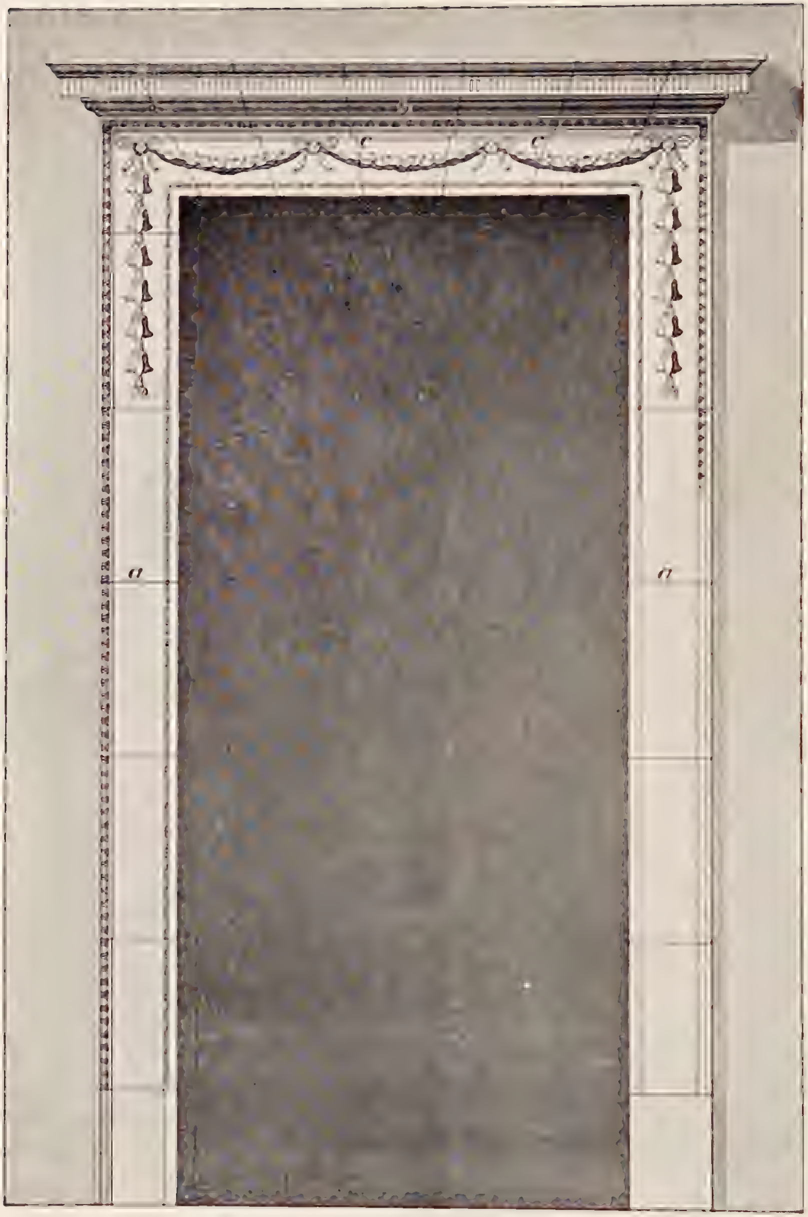


Fig. 7

it is always necessary that the projection of the pieces composing the cornice shall be less than the portion extending into the wall. A terra-cotta cornice, however, does not require this, as the various pieces may be made to enter the wall only from 9 to $13\frac{1}{2}$ inches, being held in place by ironwork embedded in the brickwork or concrete. Small rods, angles, or beams are sometimes used to support the projecting pieces of a cornice. If the projection is considerable, the inner ends of the beams should be anchored by rods carried down into the wall until there is enough above the anchor to ensure stability. If anchors are to be used for securing the cornice, it is necessary to determine the method of anchoring before the pieces are moulded, as, in manufacturing them, holes or slots must be made to accommodate the anchors.

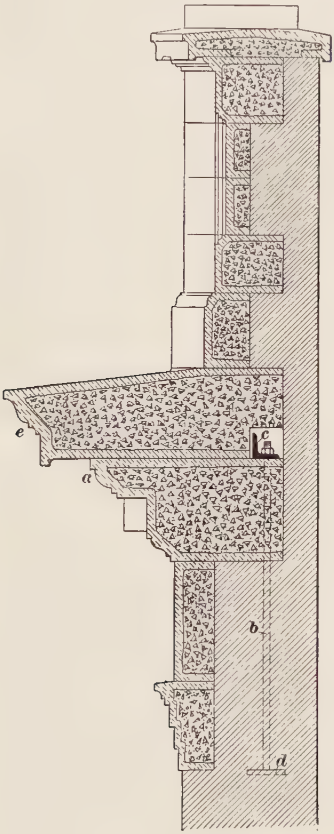


FIG. 4

16. Two methods of placing and anchoring terra-cotta in a cornice are shown in Figs. 4 and 5. In Fig. 4 is represented a cornice having a projection of 2 feet. At *a* is shown the bedmould extending into the wall, and held in place by an iron rod *b* bolted to the angle *c*, which runs longitudinally through the wall; the rod *b* has an anchor plate *d* at its lower end. Above *a* is shown the corona *e*. Fig. 5 shows a section of a cornice having a projection of 3 feet. In this case the blocks are anchored back by means of a long cramp *a* bound over the girder *b* which is embedded in concrete *c*. This cornice

has modelled enrichments on the face of some of the members, as shown at *d d*, and is covered with lead *e* to protect it from the weather. At *f* is shown some of the terra-cotta finishing to the wall-face above the cornice, and the space in between the cornice and this work *f* is carried out in brick, as shown at *g*. The majority of terra-cotta cornices will lend themselves to treatment by either of these methods.

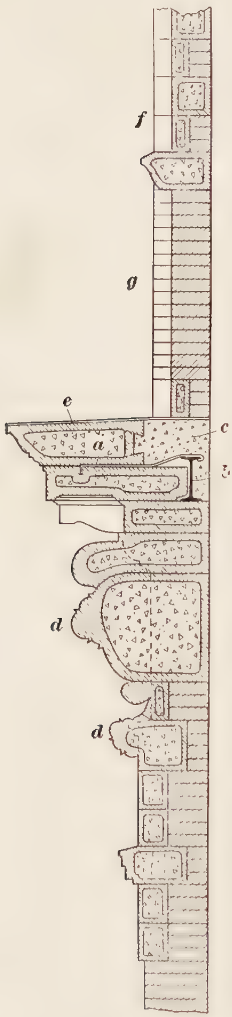


FIG. 5

17. Examples of the use of terra-cotta in modern buildings are given in Figs. 6 and 7. Fig. 6 illustrates the main façade of the Natural History Branch of the British Museum in Cromwell Road, South Kensington, which was designed by the late Alfred Waterhouse, R.A., and completed about 1879. It illustrates the use of terra-cotta on a very large scale at a time when the material was again rising into great favour among prominent architects. In this building terra-cotta has been used throughout for the facing material of the principal façades, a warm buff terra-cotta clay from the coal measures of Tamworth, in Staffordshire, having been selected. The plan consists principally of a central hall, about 170 feet by 57 feet, on each side of which are lateral galleries about 230 feet long, the ends being terminated by square pavilions with octagonal upper stories and high-pitched roofs. Behind these wings are situated other galleries parallel with the central hall. The main façade to the south is nearly 700 feet long, the principal entrance being in the centre and consisting of a lofty portal of about 40 feet span, with great splayed jambs which are decorated with

Fig. 6

disengaged shafts. The ornamental features on the exterior and interior of the building, such as capitals, strings, bosses, etc., are modelled with ornament typifying the uses of the building, in the form of conventionalized representations of extinct and living

Fig. 7

animals, birds, fishes, and plants. Alternate voussoirs to the ground-floor windows and bands at various levels are executed in a dark grey or black terra-cotta, which was produced by a cobalt preparation in the mixture of the clay. In the immediate

neighbourhood of the Natural History Museum are several large buildings in which terra-cotta has been used extensively; these are the Royal Albert Hall, the Science Schools, and the Central Technical Institute, all of which would well repay a careful study of their details, so as to gain a good knowledge of the various forms in which terra-cotta may be utilized in the design of a building. By careful observation, information may be gained as to its weathering qualities in the London atmosphere.

Fig. 7 shows the main elevation of the large block of offices erected for the Prudential Assurance Company, Ltd., in Holborn, which also was designed by Waterhouse. This building, which was erected on the site of Furnival's Inn, covers an area of 12,250 square yards, forming an isolated block extending from Holborn to Greville Street and from Brooke Street to Leather Lane, forming a main façade to Holborn of about 310 feet. The first portion at the left-hand corner of the main front was erected in 1878. The elevation of this differs considerably from the succeeding additions, which were made about 1900; an effect of symmetry, however, was achieved in the design. In this example, the terra-cotta is combined with polished red Peterhead granite and red brick, the granite extending upwards to the springing of the ground-floor windows. All the ornamental features are executed in terra-cotta, which was manufactured from Ruabon clay, and is of the strong red colour associated with that material. The inner walls are lined with faience in the principal offices, and with glazed bricks in the secondary rooms; the whole building therefore shows a most extensive use of clay materials in various forms. Under the tower-like pavilion in the centre of the façade is the principal entrance, consisting of a wide archway conducting into a series of court-yards, the arched passage being groined with terra-cotta. Many similar buildings, representing the provincial branch offices of the same company, have been erected in different parts of the country, so that the weathering properties of this particular terra-cotta, when subjected to various atmospheric conditions, can be judged.

FAIENCE

CONSTRUCTIONAL AND APPLIED FAIENCE

MANUFACTURE AND APPLICATION

18. Faience.—The word **faience** was originally applied to the glazed and richly coloured or enamelled pottery manufactured at Faenza, one of the chief seats of the ceramic industry in Italy in the 16th century. It is now, however, applied indifferently to all the various kinds of structural and ornamental glazed or enamelled earthenware and stoneware used in building, with the exceptions of glazed or enamelled bricks and sanitary pottery. Beautiful effects can be obtained with a judicious use of faience, owing to the large range of colours available and to the soft and rich effects of the covering glaze. The colour is always bright and permanent, and the surface capable of being cleaned easily when necessary. Complete structures, such as the façades of buildings, or isolated features such as fountains, vases, fireplaces, etc., requiring a striking treatment can be executed appropriately in this material. Faience applied to architecture may be divided into two classes, *constructional* and *applied*.

19. Glaze and Enamel.—Considerable confusion arises from the indiscriminate use of the terms *glaze* and *enamel*, so that the following distinction will be made here. Both are practically glass and both may be coloured, but **glaze** is applied to a transparent glass coating and **enamel** to an opaque. Glazes are prepared by fusing sand or other silicious material with potash or soda to form glass. To render glazes more readily fusible at a lower temperature, oxide of lead is added, producing the *plumbeous*, or *lead*, *glazes* which, owing to the danger to operatives

arising from the use of lead oxide, are being replaced where possible by *leadless glazes*. The addition of oxide of tin to the plumbeous glaze produces an opaque white enamel, and both glaze and enamel are variously coloured by the addition of metallic oxides.

20. Constructional Faience.—**Constructional faience** is practically glazed or enamelled terra-cotta; it is made in block form and built into the wall. It differs from terra-cotta only in the nature of the material, the greater care in preparation and burning, and in the fact that the surface is covered with a transparent glaze or an opaque enamel, generally, but not invariably, produced by coating terra-cotta that has once been fired with materials which, on refiring, produce the glaze or enamel.

21. Applied Faience.—**Applied faience** is made in the form of thin slabs or tiles, which are manufactured by two principal methods. The *plastic process* is used for pieces larger than 12 inches by 9 inches, and is similar to the method adopted for terra-cotta and constructional faience. The clay is carefully prepared, worked into a condition resembling putty, and is then pressed by hand into plaster moulds, embossed or impressed with the desired pattern. Panels are made thus about ½ inch thick, and up to 40 inches by 20 inches, with remarkable accuracy.

Applied faience in pieces less than 12 inches by 9 inches is made by what is known as the *dust process*, which applies also to the manufacture of tiles in general. The clay is prepared in a huge mixing vat, called a *blunger*, and worked into a liquid condition. This liquid clay is then passed through a series of sieves of extreme fineness, and is afterwards brought back to solid form by being passed through a filter press or by a similar mechanical process. The solid matter is then thoroughly dried, reground to a state of fine meal-like dust, and sifted, after which it is slightly moistened and compressed into shape in hollow steel moulds between two dies by means of a powerful screw. The tile press by which this operation is performed is shown in part in Fig. 8, with the customary accessories: *a* is the dust clay; *b*, the metal box in which the tiles are pressed; *c*, the plunger which descends on the dust clay in the mould, exerting great

pressure ; *d*, the metal die, which is inserted in the box to impress the ornament on the tile. When the tile is taken out, it is quite solid, as shown at *e*, and can be easily handled. It is then dressed, or trimmed, as required, and dried very carefully for

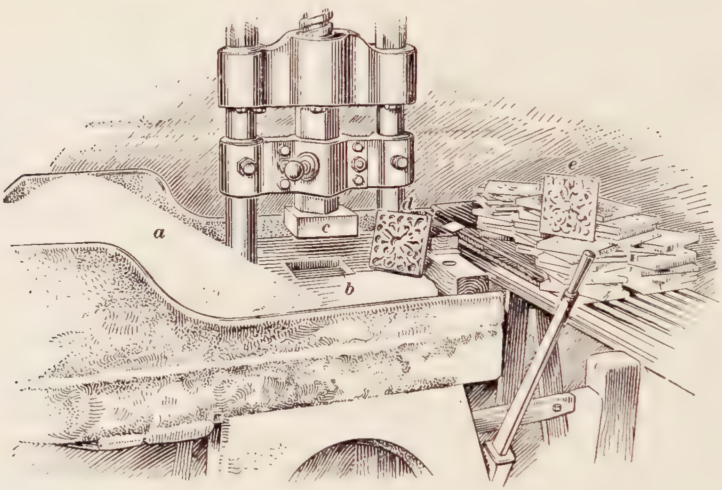
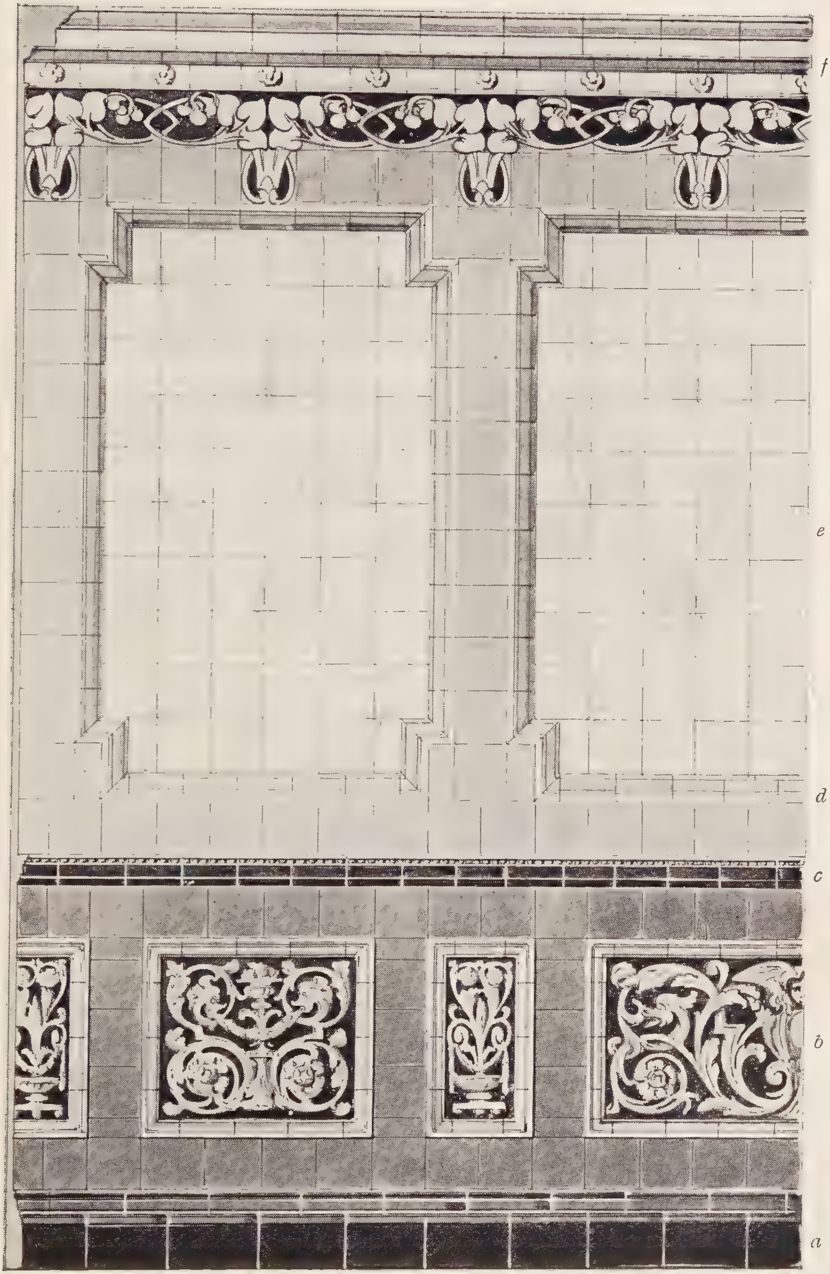


FIG. 8

some days, after which it is burnt to the state called *bisque*. The tiles are then dipped, or otherwise coated, with a white or coloured glaze or enamel, and refired, the result being a glossy surface of the desired colour.

22. Faience in Decoration.—Fig. 9 illustrates the use of applied faience in the decoration of an interior wall surface by means of tiles forming a moulded plinth *a*, dado *b*, moulded dado capping *c*, and panel mould *d* enclosing a panel of plain tiles *e*. The whole is surmounted by a cornice *f*. The scheme could be carried out in many different ways, so far as colour is concerned, to harmonize with the design of the remainder of the building in which the finishing is placed. In Fig. 10 is shown another example of applied faience. This is somewhat more elaborate than the example given in Fig. 9. The plinth *a* is moulded as before, but is made in two heights, while the dado *b* is decorated with panels of embossed tiles, giving relief to the plain tile



17

Fig. 9

border and filling to same. The dado capping *c* consists of two moulded members filled in between with decorated tiles, which could be either embossed or plain, at the pleasure of the designer. The general wall face *d* above the dado is filled in as shown with plain and embossed tiles, giving a very pleasing effect, and the whole wall-face is finished with the capping *e*, frieze *g*, and moulded cornice *f*. The frieze, as will be seen, is somewhat elaborate in treatment, but yet does not look heavy when considered in conjunction with the plain wall-face beneath.

23. Faience With Non-Reflective Glaze.—Owing to the objection frequently urged against architectural full-glazed faience, that it obliterates the design by reflection, a ceramic material is now in great use, which is not strictly to be classed with either terra-cotta or faience, but belongs perhaps more properly to the latter. This material is finished with a dull semi-glaze, variously described as *egg-shell* or *matt glaze*, and is shown in the chief market forms called Carrara ware and Marmo terra-cotta. These are hard-fired stoneware that are coated, while still in an unfired condition, or clay state, with an opaque enamel, and both body and enamel are brought to completion in the one firing at a very high temperature. This type of faience can be obtained in a large range of colours; the general practice of architects who have used the material most successfully, however, has been to design their buildings principally in the white or cream ware, resembling uncoloured marble, and to rely on brilliant colour in special situations where its use will be most effective.

24. Fig. 11 illustrates an excellent example of the use of the special type of faience just referred to. In this façade, which is the street front of a restaurant in London, the architect has emphasized the plastic character of the material, the detail being characterized by great originality. The general treatment of this façade, and the happy introduction of brilliant colour and high relief in the medallions, which are reminiscent of the splendid ceramic productions of the Della Robbia family in Italy, make this building full of suggestion for the legitimate and effective use of ceramic material in architecture.

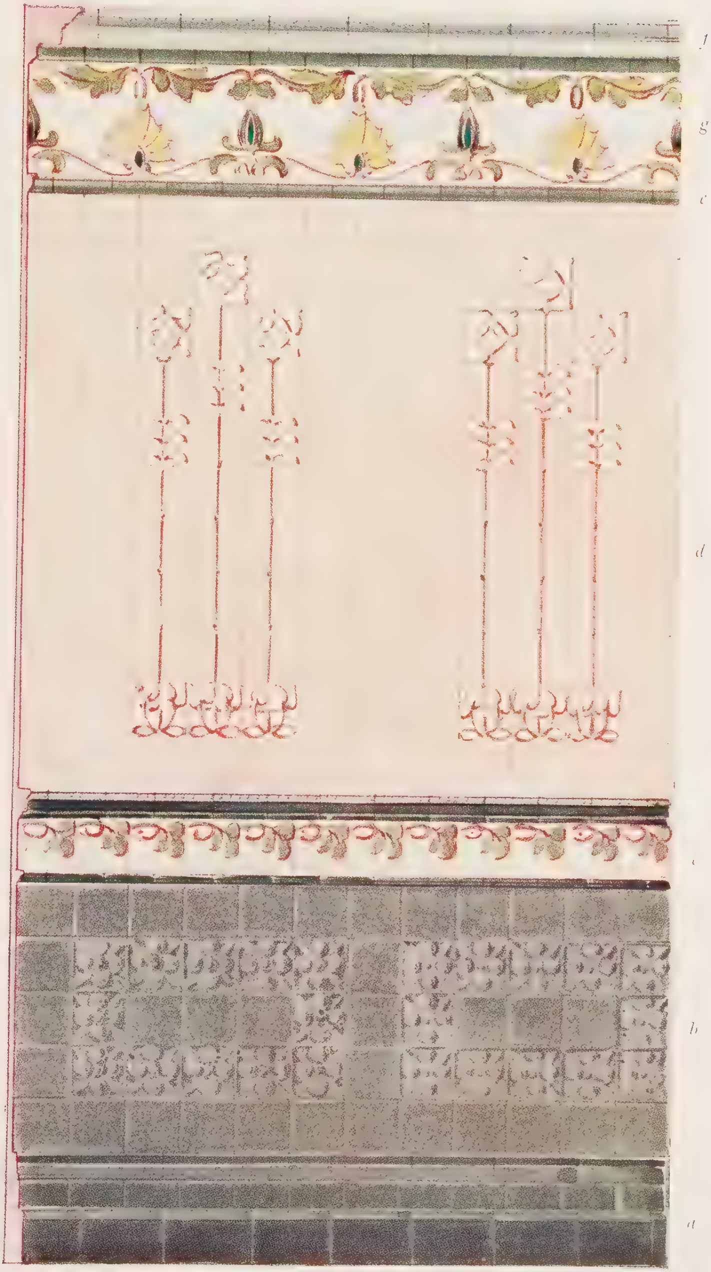


FIG. 10

Fig. 11

TILING

CLAY TILING

ROOFING AND WEATHER TILES

25. Roofing and Weather Tiles.—Tiles for roofing purposes and for the external covering of walls, called weather tiling, or vertical tile hanging, are manufactured in a manner similar to bricks, but of strong or plastic clays prepared with greater care. The usual varieties are *plain tiles, pan tiles, Roman tiles,* and *interlocking tiles.* The method of applying tiles to roof surfaces will be dealt with in *Roofing.*

26. Plain Tiles.—Plain tiles, Fig. 12, are rectangular slabs or plates of baked selected brick earth, about $10\frac{1}{2}$ inches by $6\frac{1}{2}$ inches by $\frac{1}{2}$ inch, which are used for the covering of roof surfaces and for vertical weather tiling. Plain tiles are made with projecting nibs *a* for hanging the tiles to the tiling battens, or with holes *b* through which the tiles are pegged or nailed, or with both nibs and holes. They are manufactured by hand or by machine, and may be obtained, with smooth or sanded surfaces, in a variety of natural or stained colours, such as red, strawberry, brown, brindle, etc. Special accessory tiles for various situations are illustrated in Fig. 13; (*a*) to (*f*) are *ridge tiles.* That shown in (*a*) is described as half-round; (*b*), half-round capped, having a flange *a* for covering the joint with an adjoining tile; (*c*), an angle or wing ridge; (*d*), the same capped at *a*; (*e*), an angle or wing roll ridge with a roll; and (*f*), an angle or wing crested ridge with a wing. For the salient and re-entrant

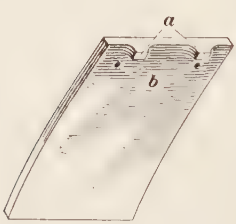


Fig. 12

angles of a roof, **hip tiles**, Fig. 13 (*g*) and (*h*), and **valley tiles** (*i*) are manufactured. That shown in (*g*) is described as a cone hip tile, with round end, and (*h*) is an angle or arris hip tile. In

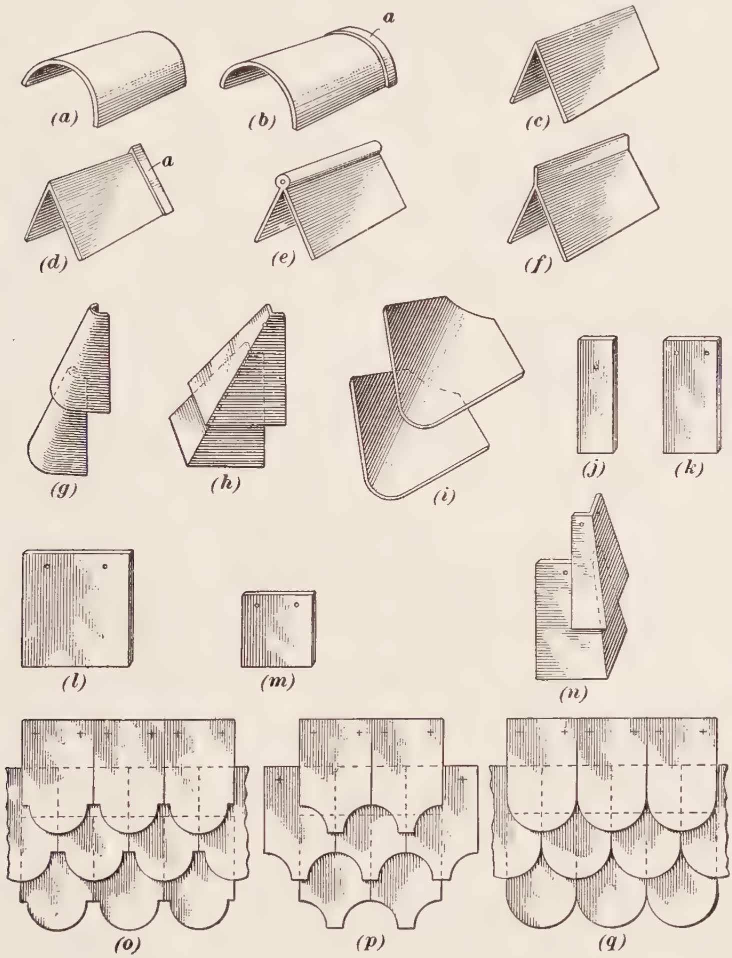


Fig. 13

addition, plain tiles of special dimensions are made for the verges, eaves, etc., (*j*) being a half-tile, about $10\frac{1}{2}$ inches by $3\frac{1}{4}$ inches by $\frac{1}{2}$ inch; (*k*), a three-quarter tile, $10\frac{1}{2}$ inches by $4\frac{7}{8}$ inches

by $\frac{1}{2}$ inch; (l), a tile and a half, about $10\frac{1}{2}$ inches by $9\frac{3}{4}$ inches by $\frac{1}{2}$ inch; and (m), an eaves tile, 7 inches by $6\frac{1}{2}$ inches by $\frac{1}{2}$ inch. Angle tiles (n) and the shaped tiles (o), (p), and (q) are used chiefly in tile hanging.

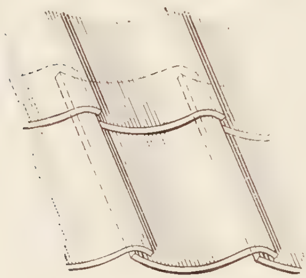


FIG. 14

27. Pan Tiles and Roman Tiles. **Pan tiles** are tiles of the special shape shown in Fig. 14. These are less expensive when laid than plain tiling, because of the reduced amount of lap involved in their use, but, owing to the quantity of moisture which they absorb, these tiles are utilized chiefly for the covering of outbuildings, and where plaster ceilings are not fixed below the tiling. **Roman tiles** of the shape illustrated in Fig. 15 are used less frequently in the United Kingdom than the types just described, but are to be found on many buildings in Continental towns.

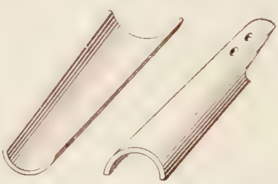


FIG. 15

28. Interlocking Tiles.—A class of roofing tiles called **interlocking tiles** has been devised for the purpose of effecting greater security in fixing, increased resistance to the

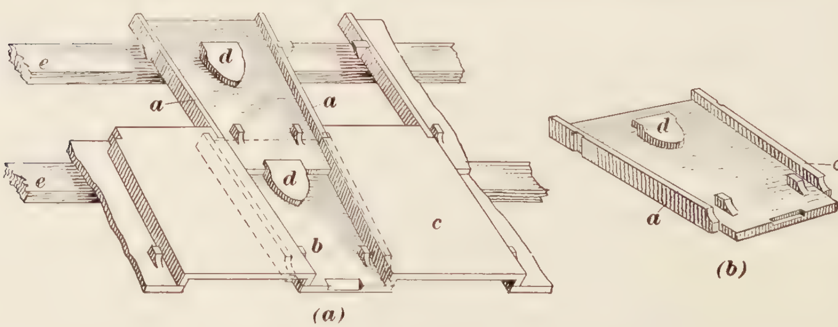


FIG. 16

penetration of moisture, and economy of material. Such tiles are generally made on proprietary systems, one of which is

illustrated in Fig. 16. The tile is specially shaped as shown, with converging flanges *a, a*, tiles being laid alternately reversed, forming in one row *b* a channel tile and in the next a capping *c* ; small nibs or projections *d* are formed on one surface of each tile for the purpose of limiting the lap and gauge. Several systems are on the market, for each of which some special feature is claimed by the makers. At *e* are shown the battens on which the tiles are laid.

WEATHER TILING

29. Vertical tiling is a distinctive feature in the elevation of certain buildings, and has the additional merit of keeping the walls dry and of an equable temperature. Tile hanging usually commences at the first-floor level, and is continued up to the eaves or cornice of the building. Occasionally, as in a house of one story, the tiling begins at a plinth level about 18 inches above the ground. The work may be either plain or ornamental, or both interspersed in bands, according to taste. Some patterns of vertical tiles are shown in Fig. 13 (*o*), (*p*), and (*q*), but many other patterns are made, and can be obtained from most tile manufacturers. Bright-red, sand-faced tiles are most frequently selected for this purpose. Special arrangements are made for finishing the tiles at external and internal angles of the building, as well as to window and door openings.

30. There are several methods of preparing for the hanging of the tiles ; when the first-floor walling is in half-timbered work, the obvious way is to fix the tile battens to the studs to the proper gauge, which is rather more than for roof tiling, a $1\frac{1}{2}$-inch lap being ample. It is more difficult to fix the tiles to a brick wall, as the tile gauge does not work in with the courses of the bricks, and, unless the bricks are very soft, which is not to be anticipated, nails cannot be driven into the work. If nailed into the joints, a 3-inch gauge only can be obtained, and this is impracticable. A $4\frac{1}{2}$-inch gauge looks well, and makes good work for vertical tiling, there being no possible chance of rain driving in. But this gauge is difficult to accommodate to brickwork, as it is not possible, without destroying the bond of

the brickwork, to build a brick-on-edge wall outside, and ordinary courses inside, in a 9-inch wall, which in ordinary dwelling houses is an ample thickness when covered with weather tiles. If a $13\frac{1}{2}$-inch wall is to be covered, this outer skin of $4\frac{1}{2}$-inch brickwork may be, and is sometimes used, although such construction

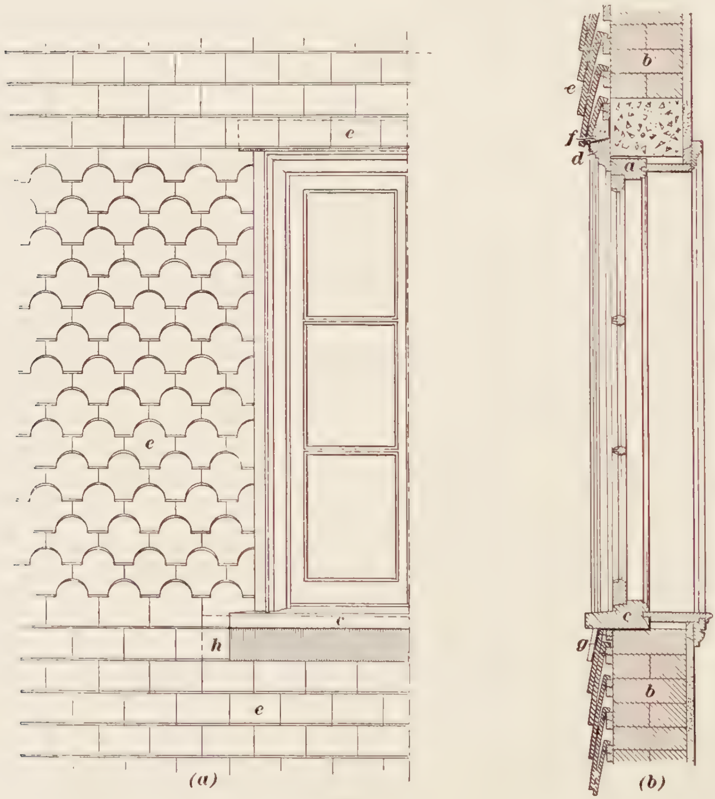


FIG. 17

is not to be recommended. The outer skin is then tied in at intervals with bonding iron ties. In this case, the joints are practically right for tile hanging with a $4\frac{1}{2}$-inch gauge. A better method is to intersperse in the outside face of the wall coke-breeze fixing bricks in every course, about 3 feet 6 inches apart, but not in the same vertical line; creosoted battens 2 inches by $\frac{3}{4}$ inch can then

be fixed to any gauge desired. This is a far better method than that which is sometimes adopted, namely, to insert wood pads $2\frac{1}{2}$ inches by 2 inches by $\frac{3}{8}$ inch thick at intervals in the vertical joints of the brickwork, for the same purpose of fixing the battens.

31. In Fig. 17 (*a*) and (*b*) the elevation and section are given of an ordinary casement window opening. The window frame *a* is set flush outside, with the brick wall *b* having a wide sill *c*. On the outside of the frame, a $4'' \times 2\frac{1}{2}''$ moulding *d* is planted on. This stops the vertical tile *e*, which must be neatly fitted against the woodwork and bedded in cement and sand mortar, which

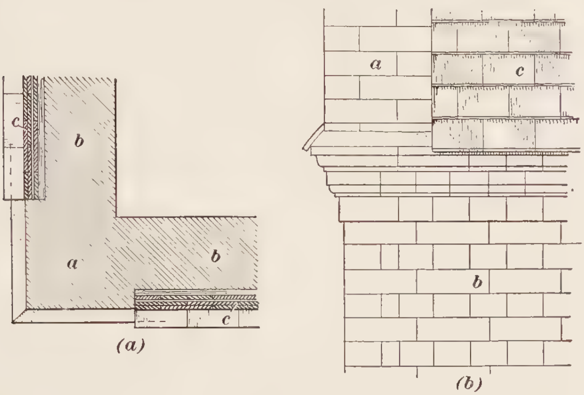


Fig. 18

must not show on the face. A piece of 5-pound lead, 8 inches wide, is dressed over the wood moulding at the head of the window opening and against the wall, as shown at *f*. The lower row of tiles is bedded on the angle of moulding, to give the necessary drip. Before the frame is put in position, a 4-pound lead seating *g*, about 12 inches wide, is laid, so that it may be turned up inside the sill, as far as the groove in the wood sill, and left for future dressing down when the tiles are laid. A cover flashing under the sill of 5-pound lead is turned 6 inches under tiles at each end of sill, and neatly dressed down with the lead seating, as shown dotted at *h*. Instead of finishing around window and other openings as just described, the frames are sometimes set back $4\frac{1}{2}$ inches from the face in a reveal, and

the tiles are merely cut fair with the reveal. The edges of the tiles are pointed, and, a groove having been run round the frame, about $\frac{1}{2}$ inch of cement and sand is floated on. No lead is used in this case, a groove only being run under the sill, so that a tile can be pushed up. This method cannot be recommended.

Fig. 18 gives the plan (*a*) and elevation (*b*) of a method of forming the angles of a building. The brickwork is carried up as a pier *a*, usually $13\frac{1}{2}$ inches wide on each face and $2\frac{1}{4}$ inches projection, against which the tiles are bedded and nailed in the usual way. The piers emphasize the angles of the building, and in some cases are not so expressionless as the following method. At *b* is shown the brick wall of the building with the vertical

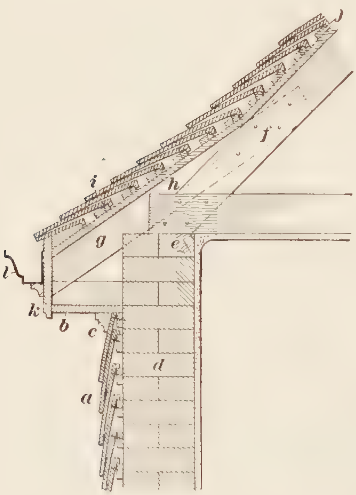


Fig. 19

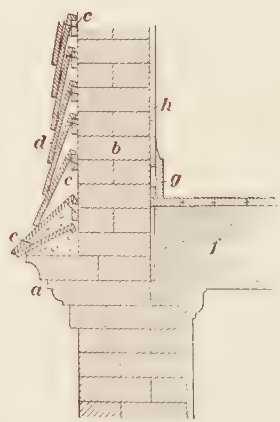
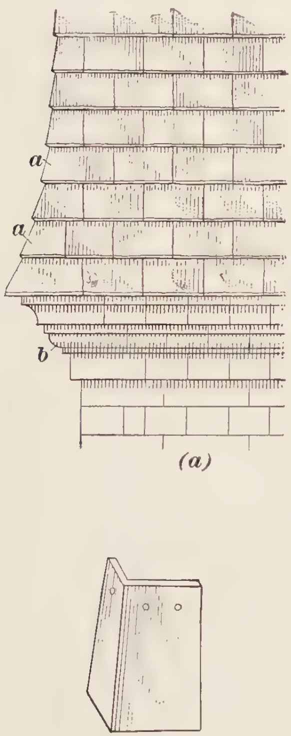


Fig. 20

tiling shown at *c*. Great care should be taken in nailing the tiles; an extra tap sometimes means a broken tile, or at least a slightly cracked one, which eventually finds its way to the ground. It may then be a difficult matter to replace it without damage to the other tiling.

32. Fig. 19 shows a method of finishing under the eaves of a roof. The tiles *a* are run up and bedded immediately under the soffit *b*; a moulded fillet *c* is then fixed to the soffit, and no

fitting to the tiles is necessary. Where there is no soffit board the tiles can be run up between the rafters, but as the vertical tiling is executed after the roof is finished, it is not an easy matter to lay the top courses, more especially if the eaves project a foot or more. At *d* is shown the brick wall, with the wall plate *e* resting on it, and supporting the rafters *f*. The sprocket piece to give a tilt to the tiles is shown at *g*, the roof boarding at *h*, with the tiles of the roof at *i*, resting on the battens *j*. The fascia is shown at *k*, with the cast-iron gutter at *l*.



(a)

(b)

Fig. 21

Fig. 20 gives a simple way to prepare for the tile hanging at the first-floor level, where the brickwork may be corbelled out as shown at *a* and the wall *b* above carried up in a line with the face of the wall below; on this face will be fixed the battens *c* to which the tiles *d* can be fixed. The lower course of tiles should be well bedded in cement, as shown at *e*, to prevent water running over the face of the tiles from penetrating through their joints into the wall. At *f* are shown the first-floor joists, and the internal plastering to the walls at *h*, with the skirting as a finish at *g*.

Fig. 21 (*a*) illustrates the use of sprocket angle tiles *a*, to give an easy curve to the corner and to ensure that the lower edge of all tiles will range to a straight line in each course. The tiling is finished on the brick corbelled course *b* in a similar manner to that described in Fig. 20. Fig. 21 (*b*) shows an ordinary angle tile obtainable either right or left hand, an equal quantity of each of which is required. Sprocket angle tiles must be ordered to the required angle. Internal angle tiles must also be used for any re-entrant angle in the tiling.

PAVING TILES

33. Paving Tiles or Quarries.—Paving tiles are made in a variety of plain colours and geometrical shapes and in several qualities. The commonest, called **Staffordshire quarries,** are coarse in texture and are made only in red, blue, and buff colours. Superior paving tiles or quarries are dense, semi-vitrified, and more carefully shaped and finished. They are obtainable in a greater variety of shapes, thicknesses, and colours, and are usually unglazed. Staffordshire quarries are made in the following sizes and thicknesses: 12 in. × 12 in. × $1\frac{1}{2}$ in., 9 in. × 9 in. × $1\frac{1}{2}$ in., $7\frac{1}{2}$ in. × $7\frac{1}{2}$ in. × $1\frac{1}{8}$ in., and 6 in. × 6 in. × 1 in. Plain geometrical floor tiles are obtainable usually in the following stock sizes: 6 in. × 6 in., $4\frac{1}{2}$ in. × $4\frac{1}{2}$ in., 3 in. × 3 in., $2\frac{1}{8}$ in. × $2\frac{1}{8}$ in., $1\frac{1}{2}$ in. × $1\frac{1}{2}$ in., $1\frac{1}{16}$ in. × $1\frac{1}{16}$ in., and in diagonal halves of the same sizes; also in octagons, hexagons, diamond shapes, etc. Rectangular tiles, and strips for bordering, are made 6 in. × 4 in., 6 in. × 3 in., 6 in. × 2 in., 6 in. × $1\frac{1}{2}$ in., 6 in. × 1 in., and 6 in. × $\frac{3}{4}$ in. The thickness of all the foregoing is usually $\frac{1}{2}$ inch. These tiles are of one colour throughout the mass, and are burnt until sufficiently impervious to resist permanent discoloration in ordinary use.

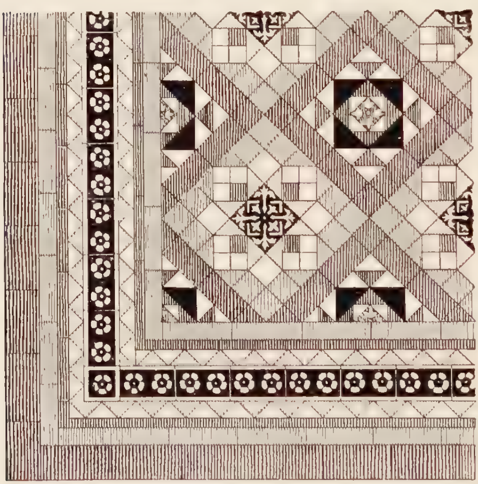


FIG. 22

34. Tessellated Tile Pavings. — Tile pavings formed of the superior paving tiles laid in geometrical patterns are called **tessellated tile pavings.** An immense variety of designs can be evolved from the stock shapes, sizes, and colours which are

available. The prices of such pavings vary with the colours utilized in forming the design, the cheapest being those in which buff, salmon, red, chocolate, grey, and black predominate. White, blue, and green are from twice to three times as expensive, and are seldom made larger than 3 inches. Fig. 22 is an example of a portion of a tessellated pavement.

35. Encaustic Tiles.—**Encaustic tiles** are those in which a pattern of one coloured clay is inlaid in the surface of a tile body of a different colour, when in the clay state, and is burnt in as part of the tile itself. The surface of the tile is level, and the pattern or design is generally complete on a single encaustic tile, but may extend over a series, a large number of varied designs being thus produced. Encaustic tiles are made either by the plastic or dust processes; in the former, a die or plaster relief is made of the desired pattern and placed at the bottom of a box mould, due allowance being made for shrinkage. Successive layers of clay are then pressed on the mould and compressed, the relief in the mould producing a sunk pattern on the tile, which is then dried and removed from the mould. Coloured clay in a semi-liquid state is then poured into the hollows formed by the die, and the tile is again dried, levelled, and fired. Dust encaustics are made by the process described for applied faience, perforated metal pattern plates and dies being used for forming the design and tile body. A class of floor tiling of somewhat limited application, which has features resembling the foregoing, may be classed as **incised** tiling; these tiles are made with sunk lines or patterns, which, in common with the joints between the tiles, are fitted with cement when the tiling is laid.

36. Ceramic Mosaic.—Mosaic paving, in which the small elements or tesseræ composing the design are made of clay, is distinguished from marble mosaic, in which the tesseræ are of marble, and vitreous mosaic, in which the material is of glass, by the title **ceramic mosaic.** Ceramic mosaic, like the other varieties to which reference has been made, is laid in corresponding forms of **Roman, or cube, mosaic** and **Venetian mosaic,** or **terrazzo.** In Roman ceramic mosaic, Fig. 23, the tesseræ are small tiles in $\frac{1}{2}$-inch cubes, made either by the dust or plastic processes and laid in

ordinary succession or in a series of concentric arcs, both of which are illustrated in the design in Fig. 23. Two methods are adopted in laying ceramic mosaic, the first of which consists in placing the tesseræ one by one in position on a prepared bed of cement, and subsequently levelling the pavement before the cement has set ; but by far the more usual procedure is to affix the tesseræ at the manufacturer's works, face downwards, with gum on a full-size drawing of the proposed design. This is divided into convenient sections, which are taken to their intended situation at the building ; the fragments of mosaic with the paper upwards are there placed in position on a prepared bed of cement, and carefully levelled, the paper being soaked with water, and removed. Ceramic Venetian, or terrazzo, mosaic is made from irregular fragments of paving tiles, those which are imperfect as whole tiles being frequently set aside and broken for the purpose of being utilized in this manner. This form of mosaic is not laid by the paper method, but is applied directly to the cement bed and carefully levelled.

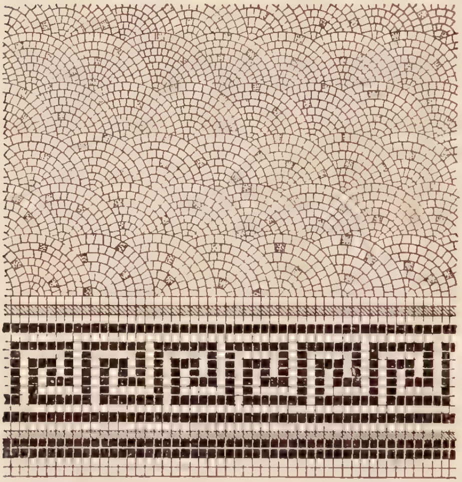


Fig. 23

WALL TILES

37. Wall Tiles.—Wall tiles differ from floor tiles principally in the fact that the former are almost invariably glazed and the latter are very rarely so. A large variety of methods of ornamentation is possible in wall tiles which would be unsuitable in tiles used for paving. But the distinction between wall tiles and the applied faience previously dealt with is of course less

marked. Applied faience and glazed tiling are frequently associated in one scheme of mural decoration under the title of applied faience.

38. Glazed and Enamelled Tiles.—The distinction before made between the terms glaze and enamel applies also to tiling, but a far greater range of glazes and enamels is available in tiles for internal decoration only, which are not subjected to severities of the weather. Glazes and tile bodies must, however, harmonize in their physical properties, fusibility, and dilatation, or the glazes will craze, chip, or peel. Tiles of coarse body are frequently covered with a layer of fine china clay in a liquid state, called *slip*, as a basis for the white or coloured glaze; the varying thickness of the latter produces a certain depth of colour. Glazes of different character are formed by the several methods of application, such as spraying, dipping or immersing, irrigation or pouring on, and volatilization. The latter is the familiar *salt glazing*, which is performed by throwing saline substances into an active kiln at the close of the burning operation. The salt is converted into vapour, which attaches itself to all exposed surfaces and forms there a thin layer of transparent glass. The brilliant decoration called *lustre* is produced by painting the design over the glaze or enamel with pigment composed of metallic salts mixed with a strong reducing agent and refiring in a special kiln, which subjects the object to the action of heated gases and smoke.

39. Embossed and Intaglio Tiles.—**Embossed tiles** are those in which a pattern or design is executed in relief on the surface, which is generally glazed in addition. When such modelling is an architectural form not complete on the single tile, the term *applied faience* is generally adopted, to distinguish the same from ordinary embossed tiling. **Intaglio tiles** are those in which the pattern is sunk or depressed. In both classes the soft plumbeous glazes will flow during burning from the higher portions of the pattern to the hollows, producing a beautifully soft effect if the action has been taken into account in the design and modelling. Tiles which are a peculiar combination of slight relief and glazing or enamelling are variously described as

having *raised outline, slip outline,* or *tube-line decoration,* the outline of the pattern being slightly raised above the general surface of the tile as a guide for the glaze or enamel painting.

40. Painted and Printed Tiles. — **Painted tiles** are of two kinds, those in which the colour decoration is applied to the once-fired or *bisque tile* before glazing, which method is called *under-glaze painting,* and those in which the painting is carried out in prepared vitrifiable colours on the glaze, and refired, called *over-glaze painting.* In some cases, tiles for wall decoration are put together in panels before or after being glazed, and a picture is painted on the panel ; the tiles composing it are then separated and fired. For large repetition of the design on a tile, methods of line and chromolithographic and other colour printing have been devised, the design being laid on the tile by means of transfers. The familiar old Dutch printed tiles with quaint and spirited designs of ships and horsemen are examples of this type of decoration in line.

FIXING TILING

41. Fixing Tiling.—Floor tiling should be laid on a prepared bed of concrete, the surface of which is covered and carefully levelled with a mortar composed of 1 part of Portland cement and 2 parts of clean sharp sand. The face of this coating should be scored or scratched to form a key for the material subsequently to be applied, and allowed to harden for at least 1 day. This surface should then be brushed to remove all dust and loose particles, and the tiles should be thoroughly soaked in water for some time before being bedded and laid in Portland cement mortar. If this precaution of wetting the tiles before use is not taken, the water is absorbed from the thin layer of cement mortar when applied, rendering the latter powdery and useless. Each tile is carefully beaten down to the proper level with the wooden handle of a trowel, and when a number of tiles have been laid the joints are grouted with liquid cement, care being taken to remove all surplus cement from the surface before the same has set. After the tile paving is laid, it is covered with

a layer of sawdust about 1 inch deep, on which planks are laid to protect the tiling against the effects of traffic until the cement has set.

When wall tiling is to be laid upon new brick walls, the brickwork should not be pointed, or, where this has been done, the joints should be raked out to form a key. In the case of fixing to old brick walls, all plaster must be thoroughly removed and the joints raked out. All walls should first be thoroughly wetted, and then covered with Portland cement mortar $\frac{1}{2}$ inch thick; the subsequent procedure is similar to that for floor tiling. Superfluous cement is rubbed off with sawdust or fine shavings.

TILING OF MISCELLANEOUS MATERIALS

GLASS TILING

42. Glass Tiling.—Glass tiling is now largely used in place of glazed clay tiling and glazed bricks, over both of which it possesses certain advantages for particular situations. It is cheaper, occupies less space, is laid with finer joints which are almost imperceptible, and has of course no glaze to craze or chip, the whole substance being of one material. Glass tiling, however, unless made with a suitable elastic backing and laid with care, is exceedingly liable to crack or fall out, and those types only should be selected in which the glass is backed with a suitable material affording a good key for attachment to the bedding material. The glass used is the opaque white or colour known as opal. Opal glass tiling is to be obtained in two principal varieties, each being described by the various manufacturers under a number of proprietary names. The chief variety, and the cheaper, is made from opal sheet glass, weighing from 15 to 21 ounces per square foot. The whole substance, including the backing material, or key, is approximately $\frac{1}{4}$ inch, and is sold cut into tiles 9 inches by 3 inches, 6 inches by 6 inches, and 9 inches by $4\frac{1}{2}$ inches, which are to be obtained in white or in various colours. Special rounded tiles are made and stocked for salient and re-entrant angles, and special sizes can be obtained

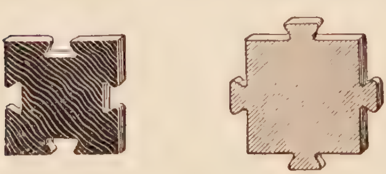
to order. The other variety is made from polished opaque plate glass, $\frac{3}{8}$ inch and $\frac{1}{2}$ inch thick, and can be obtained in stock tiles or sheets 2 feet 6 inches by 1 foot 3 inches, and up to about 8 feet by 4 feet if specially ordered. This material is about four times as expensive as the opal sheet-glass tiling.

MARBLE TILING

43. Marble Tiling.—Marble in small slabs, sometimes referred to as **marble tiling,** is largely used for paving halls and corridors in public and private buildings, and is exceedingly effective and durable. The most usual paving of this description is carried out in squares of alternate black and white marble, laid straight or diagonally, the squares being from 12 to 18 inches in size. This pattern may be associated with a border of broad continuous stripes of alternate black and white marble. When various coloured and figured marbles are used the disposition of the colours requires great judgment, and only those marbles should be associated which are equally durable. Marble tiles should be not less than $\frac{3}{4}$ inch thick for slabs up to 12 inches, and 1 inch thick for those up to 18 inches in size. Marble paving is laid on a concrete bed, floated with Portland cement and bedded in the same material. Parian cement is used for pointing and setting in the case of marbles which would be stained by Portland cement.

RUBBER TILING

44. Rubber Tiling.—**Rubber paving tiles** are used for situations in which the qualities of noiselessness and secure foothold are of primary importance. They are made of a special composition of vulcanized rubber mixed with other substances, the nature of which is not disclosed by the manufacturers, and are designed on an interlocking principle which is of great value in keeping the edges of the tiling firmly in place.



(a) FIG. 24 (b)

Fig. 24 (*a*) and (*b*) shows the two elements of interlocking rubber tiling, which are $\frac{3}{8}$ inch thick and average $2\frac{3}{8}$ inches square, or $25\frac{1}{2}$ tiles to 1 square foot. Rubber tiling is laid dry for ordinary situations, such as in church aisles, corridors, and public or private offices; but where much flushing with water is to be anticipated, as in the gangways round a swimming bath, etc., the rubber tiling is laid in a special composition supplied by the manufacturers. A complete design for paving in rubber tiles is shown in Fig. 25.

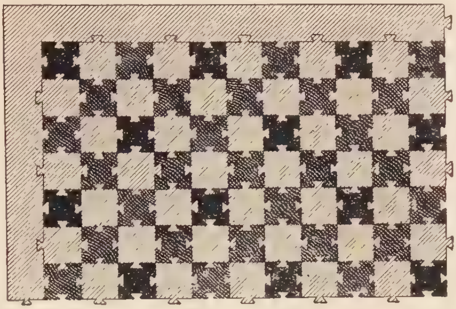


Fig. 25

BUILDING STONES

VARIETIES OF STONES

INTRODUCTION

1. In order to be able to decide which sort of stone is best to use under given conditions, a knowledge of the properties of the different kinds employed in building is essential. It is not necessary for an architect or builder to know the exact composition of a stone, but his knowledge should be sufficient to aid him in specifying or selecting the sort of stone best adapted to the purpose for which it is intended. In this Section will be described some of the principal building stones of this country, according to their geological, physical, or chemical classification.

GEOLOGICAL CLASSIFICATION

2. The strata that compose the earth's crust are classified by geologists into: (1) four great divisions, according to the animals and plants, extinct or living, that they contain; and (2) three great classes, according to the manner of their origin. The first classification, while of much importance to the student of geological history, has little interest for the architect or builder. The second classification, relating to the formation of the rock masses, has some value in determining the probable durability of a stone.

3. Classification According to Origin.—The three classes of the second classification are designated as follows:

1. The **igneous** (produced by fire), or **azoic** (devoid of life), **rocks.** Rocks of this class, such as granites, etc., owe their formation to the solidification of molten minerals.

2. The **sedimentary,** or **aqueous, rocks,** which have been formed by (*a*) the chemical precipitation of mineral matter from water; (*b*) the action of animals and plants, as shown by shells; or (*c*) the mechanical destruction, and subsequent deposition, usually by water, of other rocks, as exhibited by the sands and clays. This class includes limestones, marbles, and sandstones.

3. The **metamorphic rocks,** formed by the transformation, or change in structure, of both the igneous and the sedimentary rocks, through the influence of heat or chemical action. This class includes all varieties of slates and schists.

PHYSICAL CLASSIFICATION

4. According to their physical structure, rocks are divided into two principal classes, namely: *stratified* and *unstratified rocks.*

5. **Stratified rocks** are the sedimentary rocks of the geological classification. They are composed of grains bound together by a cementing medium, and usually consist of a series of parallel layers indicating their deposition from water.

6. The **unstratified rocks** belong to the igneous and metamorphic classes. They are, for the most part, composed of an aggregation of crystalline grains connected together without the interposition of a cementing material.

CHEMICAL CLASSIFICATION

7. Chemically, stones are divided into three great classes, namely: **silicious stones,** in which silica is the predominant substance; **argillaceous stones,** in which alumina is the predominant substance; and **calcareous stones,** in which calcium is the predominant substance. Some or all of these substances are always found mixed or combined in different proportions.

PRACTICAL CLASSIFICATION

8. For building purposes, architects and builders divide stones into the following classes: granites, limestones, sandstones, and slates.

VARIETIES OF STONE

GRANITE

9. **Nature of Granite.**—Granite is an igneous rock of granular structure, consisting of an aggregation of quartz, feldspar, hornblende, and mica. Quartz is the chief constituent and may be black, white, or grey. Feldspar is of a crystalline nature and its colour gives the tone to the mass. The durability of granite depends principally on the proportion of quartz it contains, on the regular distribution and quality of the feldspar, on the smallness of the mica grains, and on the absence of iron in any form. Feldspar makes the stone easy to cut and more susceptible to decomposition, while mica renders it friable. Hornblende renders the stone tough and heavy and is found principally in the varieties known as syenites. Granite can be obtained in many colours, white, grey, and shades of red being the most common.

10. **Distribution of Granite.**—Granite is found in many parts of the British Isles, but the chief supply is obtained from Aberdeenshire and Cornwall. The grey variety is found principally in Aberdeenshire, Cornwall, and Devonshire, while the red variety is found in Aberdeenshire, Isle of Mull, Cumberland, Westmorland, and Galway. The Scottish granites are considered the best, as the quartz in them is more abundantly and equally distributed. The red variety from Peterhead, Aberdeenshire, is one of the finest varieties in the British Islands, and is largely used for constructional and decorative purposes. Rubislaw, Aberdeenshire, is a fine-grained variety of blue-grey colour, is almost indestructible, and is applicable to the finest work. Ireland supplies many classes of good, useful granites, some of

them of a handsome type and pleasing colour. De Lank granite, from Cornwall, is one of the best known of the English varieties, and is highly appreciated for its density and light grey colour. A large quantity of granite is imported from Norway and Sweden, that from Norway being of excellent quality, easily quarried, and cheaply worked. It is extensively used in London and other large towns, the fineness of its grain allowing it to be worked to any detail.

11. Quarrying Granite.—Granite may be quarried easily, as it cleaves with regularity and can usually be obtained in any size desired. There is very little waste in a granite quarry, as the larger pieces are used as building blocks, the smaller for road metal, and the chippings for the manufacture of artificial stone. Owing to its hardness and toughness, however, great difficulty is experienced in working this stone by hand ; but with the aid of improved machinery the expense of working it has been much reduced and it is now frequently used in modern buildings, plain and moulded, as well as carved. It is better to have the stone dressed at the quarry, as it is easier to work before the quarry sap has dried out, and the saving in freight is also a consideration. It is capable of taking a high polish, which makes a beautiful and durable finish.

12. Advantages and Disadvantages of Granite.—Granite is probably the best stone for foundations, and is extensively used in other positions requiring great strength ; it is also used for templates, paving setts, kerbs, water channels, and steps. All kinds of granite are damaged considerably by the action of fire, which causes them to crack badly. They disintegrate at temperatures ranging from 900° to 1,000° F. The average weight of granite is about 166 pounds per cubic foot.

13. Syenite.—Syenite and **syenitic granite** consist of quartz, feldspar, and hornblende, the latter taking the place of mica in ordinary granite. It has a granular texture, and is usually classed as a granite for building purposes. It is hard, tough, and durable, and takes a fine polish, is of a dark green colour, and is chiefly used for paving.

14. Gneiss.—**Gneiss,** which is also a crystallized rock, is constituted similarly to granite, but is distinguished from it by being arranged somewhat in parallel layers. Owing to this peculiarity, the rock splits into slabs having approximately parallel surfaces, thus making it valuable for walls, street paving, etc. Gneiss is called *stratified*, or *bastard, granite* by quarrymen.

15. Trap.—Trap is a rock consisting of hornblende and feldspar. It breaks into blocks with ease, but has no apparent granular structure. Owing to the difficulty of quarrying this rock in large pieces, it is seldom used as a building stone, although it makes an excellent aggregate for concrete.

16. Basalt.—**Basalt** is a compact rock consisting chiefly of feldspar, augite, olivine, magnetite, and titano ferrite. It is of a dark green or black colour; but as it is very difficult to quarry, it is chiefly used for paving setts and road metal. It is found in the North of Ireland, the Hebrides, and the North and Midland Counties of England.

17. Whinstone.—**Whinstone,** or **greenstone** as it is sometimes called, is distinguished from basalt by its containing hornblende. It is a hard durable rock, usually of a blue-grey or blue-green colour. It is difficult to quarry this stone in blocks of any considerable size, but in the neighbourhood of the quarry it is largely used for rubble building and field stone walls, or dykes as they are called in Scotland. It is also used for road metal. It is found in most parts of Scotland and in the North of England.

18. Elvan.—The stone known as **elvan,** or **elvanite,** is a fine-grained crystalline rock, composed of quartz and orthoclase (a variety of feldspar), found in Cornwall and Devonshire. It resembles granite, but is without mica. It is used locally as a building stone, and also for road metal.

LIMESTONE

19. The **limestones** used in building consist of carbonate of lime in combination with one or more of the following constituents: silica, carbonate of magnesia, clay, and iron.

Fossil remains, such as shells, coral, etc., usually in a more or less pulverized condition, are frequently found in them. The term limestone is very general, and includes many varieties. Not all of these are suitable for building purposes, however, and care and experience are required to make the proper selection, particularly for town buildings.

20. Classification of Limestones.—Limestones may be grouped as follows, according to their physical and chemical structure :

1. **Simple,** or **compact, limestones,** smooth in texture and even-grained, consisting principally of carbonate of lime. When sufficiently hard to take polish they are called *marbles.*

2. **Oolites,** composed of minute egg-shaped particles of carbonate of lime cemented together by the same material.

3. **Magnesian limestones,** composed principally of carbonate of lime, but containing not less than 10 per cent. of carbonate of magnesia. When a limestone contains just over 45 per cent. of carbonate of magnesia it is known as a *dolomite.*

4. **Carboniferous limestones,** which are sufficiently hard to take a polish. These limestones are generally called *marbles.*

21. General Nature of Limestones.—In colour, limestones are generally white, cream, light grey, blue, or buff. Good examples are those obtained from Lincolnshire, Derbyshire, Wiltshire, Somersetshire, Dorsetshire, Kent, and Nottinghamshire, and may be classed among the best building stones. Limestones, although durable, are easily stained by the smoke in large cities. They weigh about 150 pounds per cubic foot, and some varieties will take a high polish. They are also easy to work, but are easily destroyed by fire.

22. Well-Known Limestones.—In Table I is given a list of well-known English limestone quarries, with a brief description of the product of each. In addition to the English limestones, there are several foreign stones in common use, among which are the **Caen** oolite from Normandy, having a fine close grain and suitable for internal work only ; and three carboniferous limestones or marbles, **St. Anne's, Sicilian,** and **rouge royal,** from Belgium, Italy, and France, respectively.

TABLE I

PRINCIPAL LIMESTONE QUARRIES IN ENGLAND

Name of Quarry or Locality	County	Colour	General Characteristics
SIMPLE OR COMPACT			
Beer Stone	Devonshire	Light brown	Not suitable for towns
Chilmark	Wiltshire	Yellowish brown	Very fine, even grain
Tisbury	Wiltshire	Light greenish grey	
Ham Hill	Somersetshire	Yellow to brown	The best are very durable
Hopton Wood	Derbyshire	Grey	Very hard; will take polish; suitable for steps
Kentish Rag	Kent	Blue grey	Very compact and heavy; hard to work
OOLITES			
Ancaster	Lincolnshire	White, yellow, pink	Weathers well
Bath	Wiltshire and Somersetshire	Cream	One of the most frequently used limestones. Can be obtained in very large sizes
Ketton	Rutlandshire	Cream and pink	Very large grain; known as Roestone
Painswick	Gloucestershire	Cream	Very even grain
Portland	Dorsetshire	Whitish brown	One of the best building stones; weathers well
Purbeck	Dorsetshire	Brownish grey	Very hard and durable; takes polish
MAGNESIAN			
Anston	Yorkshire	Cream brown	Weathers well
Bolsover	Derbyshire	Light brown	Very suitable for town buildings
Huddlestone	Yorkshire	Cream	Hard veins occur in the stone
Mansfield	Nottinghamshire	Yellow	Very durable stone; a dolomite

MARBLE

23. Marble is a crystallized limestone, hard enough to take a polish. It can be obtained in many colours: white, grey, red, blue, green, black; and most of its varieties will take a high polish. One of the most important characteristics of marble is that it is easy to carve; the finer the grains of the stone, the more suitable it is for this purpose. The fine white-grained varieties that are especially prized for sculpture are called *statuary marble*.

24. Marble is a valuable material for interior construction and decorative purposes, such as staircases, hearths, kerbs, chimney pieces, table and lavatory tops, steps, floors, and wall linings; but, like all limestones, it will not withstand fire.

Some good varieties of coloured marbles are obtained from Devonshire, Cornwall, Derbyshire, Cumberland, Galway, and Iona. The white variety is imported from Italy and Greece, and the coloured from Italy, Greece, Belgium, and several other countries in Europe, and North Africa.

25. Onyx Marble. The term **onyx** is applied to some kinds of marble for the reason that their banded appearance somewhat resembles that of true onyx. These marbles have the same general composition as the common varieties of marble, but are formed in a purely chemical manner instead of in ordinary sedimentary beds. Their variegated colours are due to the presence of metallic oxides and other impurities.

Onyx can be worked and polished very readily, and is considered the handsomest of building stones, owing to its translucence and great variety of colours. It is used almost entirely for interior decoration, wall panelling, columns, mantels, etc. The stone presents the best appearance when cut across the grain, but this impairs the strength and necessitates a backing of stronger marble. Most of the onyx used in this country comes from Mexico and Algiers.

26. Serpentine.—Serpentine resembles marble in appearance, but is composed of hydrated silicate of magnesia, and contains

little or no lime. It is easy to work, and will take a fine polish, but is suitable for internal work only. The colour varies considerably, but the prevailing colours are green, red, and brown, permeated by veins of white steatite. The best known variety is the lizard serpentine from Cornwall, and also found in Ireland and Scotland.

SANDSTONE

27. Sandstone is so called because it is generally formed by the cementing together of particles of sand, usually quartz. The character of the stone depends greatly on the nature of the cementing material. If the grains have been cemented by fusion, or under great pressure, the stone is nearly as hard as quartz ; this variety is known as *quartzite*, and is very strong and durable. When the cementing material is silica, the stone usually has a light-grey colour and is hard to cut ; but if the grains are cemented by oxide of iron, the stone is either red or brown, and is much softer. With carbonate of lime as a cement, the result is a light-coloured or grey stone, soft and easy to work, but does not, as a rule, weather well. Sandstone containing clay is the poorest, as it easily absorbs water, which, on freezing, rapidly disintegrates the stone.

Sandstones vary in texture from those in which the grains are almost imperceptible to those having grains like coarse sand ; the finer the grain, the more easily can the stone be carved. Quarried sandstones usually hold a considerable amount of water, which renders them soft and easy to work ; but nearly all become harder as the water evaporates, and the stone should not be subjected to heavy loads until the water is dried out.

Sandstones include some of the finest and most durable stones for outside construction. The ease of working them and their wide distribution cause them to be very extensively used. The stone is found in a great variety of colours, shades of grey, brown, buff, pink, red, drab, and blue being common, which depend largely on the quantity of iron oxides contained in the stone. The presence of these is not injurious, but no sandstone containing iron pyrites should be used for exterior work, as it is almost sure to become stained by rust.

28. Classification of Sandstones.—Sandstones may be divided into groups according to their composition. Those containing a large proportion of mica are called *micaceous*; those having a large proportion of lime, *calcareous*; while *feldspathic sandstones* contain a large proportion of feldspar. They are also often classified according to the purposes for which they are to be used, as *flagstones*, *tilestones*, *freestones*, and *grits*.

29. Flagstone is a thin-bedded variety of argillaceous, or clayey, sandstone having a bluish colour. It is very hard and dense and splits easily along the line of stratification into thin sheets or flags, and makes an excellent material for foundations, pavings, etc.

Tilestones are similar to flagstones, but are taken from thinner beds. They are used for roofs in some districts.

Freestone is a term used for any stone that can be worked freely with mallet and chisel.

Grits are strong heavy sandstones used for heavy engineering works, being especially valuable from the fact that they can be obtained in large blocks.

30. Well-Known British Sandstones.—The **Bramley Fall** sandstones are light brown in colour, coarse-grained, durable, and are suitable for steps and heavy engineering work. The **Craigleith** sandstones, from near Edinburgh, are of a whitish-grey colour, are very fine-grained, and contain about 80 per cent. of silica. This is perhaps the finest and most durable sandstone found in the British Isles for building purposes. The sandstone from **Darley Dale,** Derbyshire, is light brown in colour, and is suitable for town buildings. The **Forest of Dean** sandstones are coloured grey or blue; they weather well and are suitable for moulded work and building generally, as well as for engineering work. The **Mansfield** sandstones are red or white; they are among the most important British building stones. The white variety is specially useful for pavings, steps, etc. The **Park Spring** stone, from near Leeds, is light brown in colour. It is like the Bramley Fall variety, but is of a finer texture. The **Robin Hood** stone, from near Wakefield, is greenish grey, and is very suitable for steps and landings.

SLATE

31. Slate is an amorphous, compact, fine-grained, argillaceous rock of somewhat similar composition to granite, but having less silica and more alumina, with traces of lime and manganese. Originally deposited by sedimentary action in water, it has been subjected to great pressure, which has developed cleavage planes quite independent of the bedding. The existence of these cleavage planes is one of the most important characteristics of slate, as it is possible to split slabs along the planes into very thin sheets. Slate is also characterized by its transverse strength and toughness and the fact that it does not absorb and retain water. It is valuable as a roof covering on account of its durability and lightness ; the larger slabs are used for larder shelves, cisterns, chimney-pieces, steps, etc. Purple, green, and blue slates may be obtained, the best varieties coming from Wales and Westmorland.

32. Schist is a variety of slate, but generally does not break easily into very thin slabs. The harder varieties are used locally for pavings, steps, hearthstones, etc.

PROPERTIES OF BUILDING STONES

33. Selecting a Building Stone.—In selecting stone for a building, it is essential to consider its strength, weight, colour, and durability, and to choose a kind suitable for the situation in which it is to be used.

Among other things, it is necessary to consider carefully the situation of the building, whether in town, country, or on the sea coast ; the character of the design and the amount of detail required ; and the distance from the quarry and facilities for transit, which will greatly affect the cost.

34. Weight of Stones.—Table II shows the average weight per cubic foot of block stone of the classes mentioned.

35. Crushing Strength.—Whenever a stone is to be used for foundations, piers, lintels, templates, etc., its strength is a

TABLE II

AVERAGE WEIGHT OF STONES

Stone	Weight Pounds Per Cubic Foot
Granite	166
Limestone	150
Marble	170
Sandstone	139
Slate	174

TABLE III

AVERAGE CRUSHING STRENGTH OF STONES

Kinds of Stone	Strength Tons Per Square Foot	Kinds of Stone	Strength Tons Per Square Foot
GRANITES			
Rubislaw	1,289·7	Carrara	620
Peterhead	1,207·7		1,400
Corrennie	1,318·3	Carrara Statuary	200
Cornwall	1,060·2		390
Irish	150	Brabant	590
	860		1,360
Norway	1,240	SANDSTONES	
LIMESTONES			
Ancaster	184	Craigleith	861·9
Chilmark	411·4	Robin Hood	574
Portland	204·7	York Stone	370
Box Ground, Bath	97·5	Closeburn	400
Corsham, Bath	94·5		626
Coombe Down, Bath	117·7	Caithness	415
Mansfield	577·4	Arbroath (paving)	500
MARBLES		Doonagore or Shamrock	
Devonshire	475		2,214
Dorsetshire	587	Mountcharles	762·2
Kilkenny	970	Bramley Fall	238·4
Galway	1,300	Darley Dale	516·7

matter of importance. In Table III is given the load in tons per square foot at which the different kinds of stone fail. The values given are from actual tests, but must be taken only as giving a general idea of the crushing strength of the various stones. As a general rule, stone should not be subjected to a greater compressive load than one-tenth of the crushing strength as given in Table III.

36. Colour.—In rural districts, and places where little or no soft coal is consumed, light-coloured stones may be used without any danger of becoming dirty or disfigured, while in very smoky cities they will get very dark in a few years. In such cases, the red or brown silicious, or flinty, sandstones are the most desirable; and next in value are the granites. The stone that retains its native colour best is the most desirable to use; but, in localities where all classes of stone change, the one to be preferred is that in which the alteration is the least, and is uniform throughout.

CONDITIONS AFFECTING THE DURABILITY OF STONE

37. Durability.—The durability of stonework is of great importance, and on this property depends the life of a structure. It is evident, therefore, that buildings should be constructed of the most durable stone that can be economically obtained in the locality in which the building is to be erected.

38. In order that a stone may be durable, it must be free (1) from internal decomposing elements, as ferric oxide in the hydrated form, sulphide of iron, feldspar showing incipient decay, carbonate of calcium, protoxide of iron, excess of non-crystalline alumina, and organic matter; (2) from cavities or fissures, either empty or filled with liquids; (3) from irregular laminæ and seams, or patches of soft material not thoroughly cemented together, technically called **drys**; (4) from veins, called **crowfoots**, containing uncemented material; and (5) from lack of uniformity in hardness, texture, solubility, and porosity.

39. Causes of Decay.—The ordinary variations of temperature test building stones most severely. Stones consist of particles

cohering more or less closely, and an increase in temperature causes each particle to expand, tending to force apart those surrounding it, while with a lowering of temperature a corresponding contraction occurs. As the temperature is ever varying, there is a continual motion of the particles, which, although very small, will in course of time produce cracks and result in the slow and gradual destruction of the stone. Such changes are among the most potent causes of the disintegration of stone.

40. The effect of frost on stones saturated with moisture is always disastrous. The expansive force exerted by water in solidifying is nearly 140 tons per square foot ; hence, a stone of open texture exposed to heavy rains and then to the action of frost must suffer deterioration in course of time. Sandstones are the most porous, and granites the least ; for this reason, granite is best adapted for use in wet places, as in foundations.

Stone should always be laid on its natural bed wherever possible. If placed so that the layers, as found in the quarry, are vertical, water penetrates between them much more easily, and, in freezing, will very quickly split the stone. Stones, such as sills and copings, so placed that rain washes over them, will deteriorate much more rapidly than the rest of the masonry, and on this account should always be of the most durable kinds. Cornice stones should be laid with the layers in a vertical position, not on the natural bed. Arch stones should be arranged so that the thrust passes in a direction perpendicular to the layers.

41. Many stones contain within themselves the elements of decomposition, and the introduction of some chemical element will often begin the process of decay by disintegration. The changes are the results of oxidization and solution. When iron exists in stone in the form of pyrites, it becomes combined with the oxygen in the air and produces the discoloration known as *rust*. When very minute, these particles of iron pyrites are not injurious, and the only effect of the rust is to give the stone a yellowish tinge ; but if the pieces are of considerable size, the oxidization will discolour the stone unevenly. Some authorities claim that the presence of pyrites in small quantities

is beneficial to the stone, as it increases the tenacity by its cementing qualities.

42. High winds are also a source of destruction, as air carries particles of hard substances, and the impinging of these against the stone, particularly the moulded features, will gradually wear away the surface. The wind also removes all particles and always leaves a new surface of stone exposed. This is particularly noticeable in buildings on the sea-coast. Lichen, moss, and other vegetable growths are also destructive agents, especially in country districts.

43. Pure water has practically no effect on building stones. Rain, however, contains traces of nitric, sulphuric, and other acids, absorbed from the smoke and other impurities in the air, and when these are brought in contact with stones, they tend to dissolve all portions that are soluble. Lime and magnesia in the form of carbonates (as in all marbles and limestones) are, in particular, easily acted on; sandstones containing iron or lime suffer from the same causes, while granites are the least affected.

44. Heavy pounding or hammering by the mason has a tendency to destroy the cohesion of the grains and thus renders the stone more susceptible to climatic influences. Only granites and the hardest sandstones should be axed or bush-hammered. The most durable surface for granite is *rock-faced*, as the crystalline facets, being but little disturbed in the dressing, do not absorb moisture readily. For other stones, however, a smooth surface is usually the best in a changeable climate. Quarrying by explosives often causes cracks in the stone that are so small as to be unseen until the application of the load increases them enough to make them visible. The fracture of stones in buildings is often due more to imperfect cutting and setting than to any lack of strength in the stone.

45. For some purposes, as for steps, door sills, paving, etc., the *hardness* of a stone is of importance, in which case granites and other hard stones are the most suitable, if they do not become slippery in wear.

46. In selecting building stone, it is often important to obtain a kind that possesses good fire-resisting properties. The fine-grained compact sandstones endure fire the best; while the exposed surfaces of limestones and marbles become converted into lime by intense heat. Granites are more affected than sandstones, but less than limestones.

47. Seasoning Stone.—In order to evaporate the quarry water that most limestones and sandstones contain when freshly quarried, they should be exposed to the air for a considerable time before being used; this seasoning makes the stone harder and also more durable under the action of frost. It is supposed that the quarry water contains in solution considerable cementing material and that this is deposited when the water evaporates, firmly binding together the particles. It can readily be seen that all necessary cutting or carving on stone of this kind should be done as soon as possible after quarrying.

INSPECTION AND TESTS

48. A close inspection should be made of all stone before it is used, to see that the specified quality is being delivered. When large quantities of stone are to be used, it is even advisable to visit the quarry in order to make any necessary tests. The tests usually made to assist in determining the qualities of stone, as to durability, etc., are for *density* and *hardness*, *absorption* and *solubility*.

49. Density.—The densest and strongest stones are generally the most durable. The density depends on the contiguity or closeness of the aggregation of the mineral grains forming the stone. The closer the grains, the denser and heavier will be the stone, and the less will be the amount of interstitial space. An idea of the density may be obtained by examining, through a good magnifying glass, the surfaces of freshly fractured stone, which should be clear and bright, with the particles well cemented. A dull earthy-looking fracture indicates liability to quick deterioration, while, if the stone gives forth a clear metallic

sound when struck with a hammer, it is a good indication of its density.

50. Hardness.—The hardness of a stone depends on the hardness of its mineral constituents and on their state of aggregation. The component minerals may be hard, but the stone itself will be soft if the particles do not adhere strongly to one another. Thus, some of the softest sandstones are composed of quartz, which is a hard mineral, but the grains are so weakly cemented together that the stone as a whole is soft. Hardness does not imply that a stone is durable: many hard stones are more affected by atmospheric agencies than those of a softer texture whose chemical composition is of a more durable nature.

51. Absorption.—The tendency of a stone to absorb water should be considered with regard to the effect on the appearance of the building. While a dense non-absorbent stone is restored to its original colour by a heavy rain, one of open texture will quickly absorb the water, which carries dust and soot into the pores of the stone and thus makes it very dirty in a short time. It must be remembered that some of the impurities in the air, particularly in towns, which cause stone to decay are soluble in water, and if the stone is very absorbent these impurities will be more readily conveyed below the surface and cause disintegration by chemical action. In order to test the absorptive qualities of a stone, a good average specimen should be thoroughly dried, carefully weighed, and immersed in water for 24 hours. When taken out, the surface moisture should be dried off and the piece weighed; from the gain in weight, a good idea of the value of the stone may be obtained. One that increases 10 per cent. in weight in 24 hours should be rejected, unless it can be proved that such stone has endured successfully the tests of time and weather. Even one absorbing 5 per cent. of water and containing a large proportion of clay is unsafe to use.

52. Local Inquiry.—Possibly the best test of durability is to examine the faces of the old workings of the selected quarry, and to observe how they have weathered, and also to examine

the older buildings in the neighbourhood that have been erected with the stone in question. It is generally found that stone suits the locality in which it is quarried better than that brought from a distance.

53. Solubility.—To determine whether a stone contains soluble earthy or mineral matter, crush finely a sample of the stone and place it in a glass of water, letting the particles remain undisturbed for about half an hour; then give the contents of the glass a rotary motion by stirring. If the stone contains much earthy matter, the water will assume a turbid appearance, while if it has only a small quantity, the water will remain clear. As already stated, the air in manufacturing cities is very likely to contain traces of various acids that decompose stone when brought in contact with it by rain and which will attack any of the constituents of the stone that are soluble. To determine the probable effect of acids on stone, soak a piece in a dish of water containing a drop or two of muriatic or sulphuric acid. If there is a very noticeable action, it will be wise to make further inquiries.

STONE CUTTING AND FINISHING

54. Before treating of stone masonry, the preliminary work of dressing the stones for the wall should first be considered. It is unnecessary for an architect to be an expert stone cutter, but he should be thoroughly familiar with the general principles in order to be able to specify the proper treatment for a certain class of work and to know when it is well done.

STONE-CUTTING TOOLS

55. Hammers.—In Fig. 1 are shown the various hammers used for cutting and dressing stone, which may be described as follows:

The **spalling, or double-faced, hammer** (*a*) weighs from 20 to 30 pounds, and is used for breaking and roughly shaping the stones in the quarry.

The **waller's, or face, hammer** (*b*) is a lighter tool than the

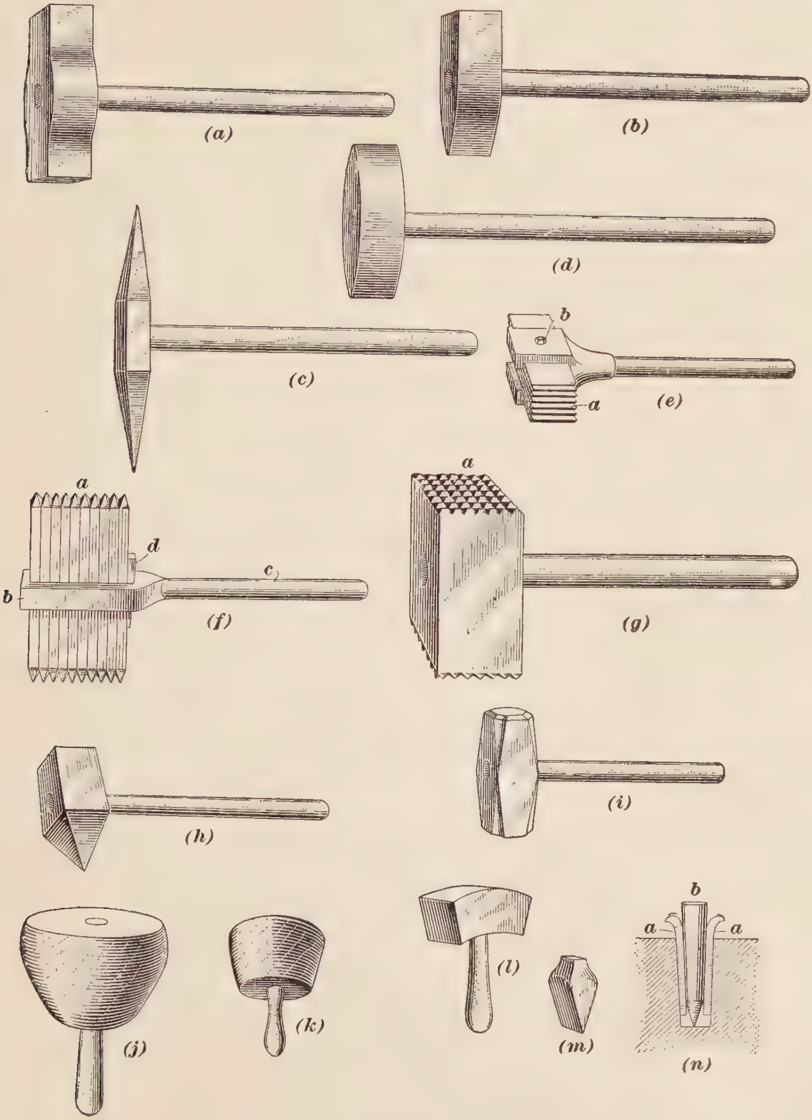


FIG. 1

spalling hammer, but is used for the same purposes when less

weight is required. It has one blunt and one cutting end, the latter being used for roughly dressing the stones preparatory to using the finer tools, and for roughly squaring stones in rubble work.

The **pick** (*c*) is used for coarsely dressing and splitting stones; its length is from 15 to 24 inches, the width at the eye is about 2 inches, and it weighs from 14 to 16 pounds.

The **axe,** or **peen hammer,** (*d*), is about 10 inches long, and has two cutting edges about 4 inches in length. It is used principally for finishing the surface of granite similar to tooled work.

The **patent axe** (*e*) is made of from four to ten thin blades of steel *a*, which are ground to an edge and bolted together, as shown at *b*, so as to form a compact piece. It is used for finishing granite or hard stone, and the number of blades required to give the proper fineness to the cutting is usually specified as four, six, eight, or ten cut.

The **crandall,** or **patent pick,** (*f*), consists of a malleable-iron handle *c* having a slot in the end *b*; in this slot are placed ten or twelve bars of $\frac{1}{4}$-inch square steel *a*, about 10 inches long and pointed at each end, which are held firmly in place by the key *d*. The crandall is used to complete the finish of sandstone after the surface has been partly worked by a chisel.

The **bush hammer** (*g*) is from 4 to 8 inches long, with ends from 2 to 4 inches square and cut into a number of pyramidical points, as shown at *a*. This hammer is used for finishing limestones and sandstones after the surfaces have been made nearly even.

The **scabbling hammer** (*h*) has one end pick-pointed, and is used for roughly dressing granite and other hard stone in the quarry.

The **mash,** or **hand hammer,** (*i*), is used for drilling holes and in pointing and chiselling the harder rocks. It is about 5 inches in length, and weighs from 2 to 5 pounds.

The **mallet** (*j*) is used when the softer stones are to be cut. It is made of hard wood, the head being about 7 or 8 inches in diameter and 5 or 6 inches in height.

The **dummy** (*k*) is similar in form to the mallet, but with a smaller head, and is generally used for carved and fine work.

The **iron hammer** (*l*) is used for carved work.

The **wedge, or gad,** (*m*), is of iron, and is used in splitting freestone.

The **wedge** and **feathers** (*n*) are generally used for splitting granite. These consist of two thin curved iron plates *a* and a conical steel wedge *b* which is inserted between them.

56. Chisels.—Chisels are divided into two classes: those for use with the hammer and those for use with the mallet. The mallet-headed chisels have their striking ends made broader than the hammer-headed, to avoid injuring the mallet. Hammer- and mallet-headed chisels are made with lengths of edges from $\frac{1}{4}$ to $1\frac{1}{4}$ inches wide; mallet-headed chisels, from $1\frac{1}{2}$-inch edge upwards, are termed *boasters*, or *scabblers*, and are used for tooling surfaces. In Fig. 2 are shown the different chisels used for dressing stone.

The **chisel point** (*a*) is made of round or octagonal steel, 8 to 12 inches long, with one end pointed; it is used with the mallet for chipping off the rough faces of the stone and reducing them to approximately plane surfaces, and also to give a rough finish to stone in **broach** and **stugged work.**

The **punch** (*b*) has an edge similar to that of the point, but is used with the hammer.

The **claw tool,** or **tooth chisel,** (*c*), is used for dressing the surfaces of hard stones after the point or punch has been used.

The **patent stone cutter** (*d*) serves the same purpose as the claw tool, having in a handy and convenient form interchangeable double teeth, or a chisel and tooling drove combined, as shown at *a*.

The **drove chisel** (*e*) is 2 or 3 inches wide at the end, and is used for cutting or cleaning off the rough surfaces of the stone, and tooling or droving the finished face.

The **boaster,** or **scabbler,** (*f*), is used for cleaning the stone after the point or punch tool.

The **pitching tool** (*g*) is used for making pitched-face work, or reducing stones.

The **chisel** (*h*) is used for making narrow draughts.

The **wood-handled chisel** (*i*) is used on Bath and other soft stones.

The **jumper** (*j*) has its cutting edge wider than the handle, and is used for boring holes in quarrying, generally for blasting operations.

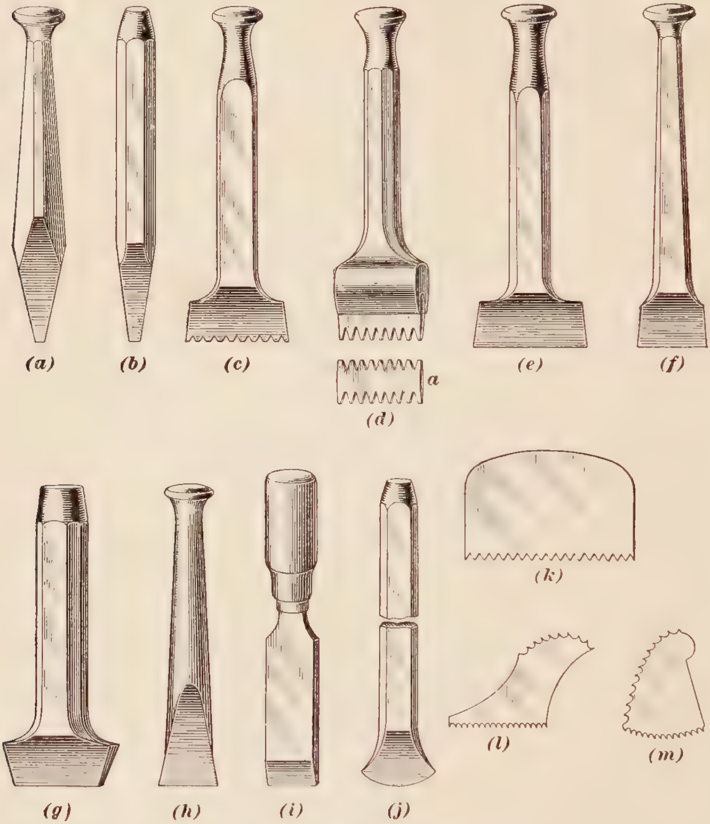


FIG. 2

The **drags** (*k*), (*l*), and (*m*) are pieces of sheet steel with toothed edges, made in various shapes, and used for working or *dragging* the surfaces of soft stone to a uniform level.

57. Setting-Out Tools.—In Fig. 3 are shown some **setting-out tools** which are necessary to the mason in setting out work.

The **square** (*a*) is generally made of iron, each arm being about 18 inches long, and set to a true right angle.

The **set square** (*b*) is formed of iron, set to 45° or other angle, as required.

The **bevel** (*c*) is formed of two strips of metal, slotted and fastened with a thumbscrew, by which they can be fixed at any angle.

The **compass** (*d*), for dividing, is generally made of iron, with sharply pointed ends, and has a thumbscrew which works against

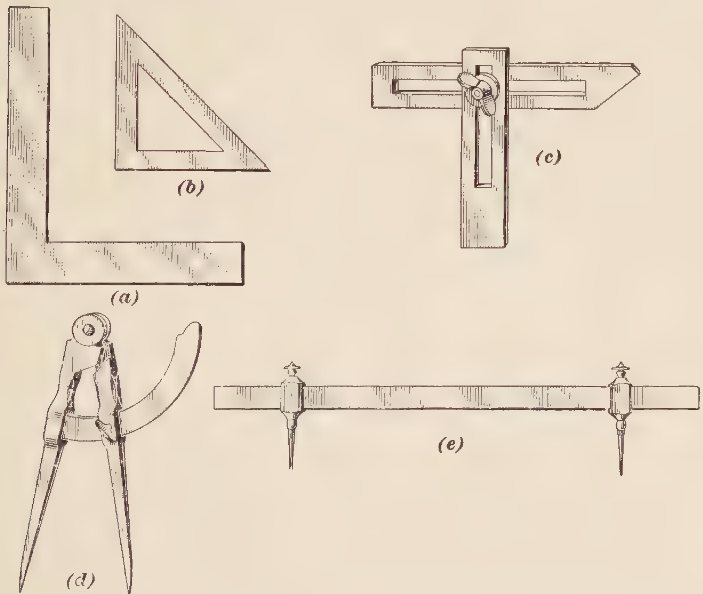


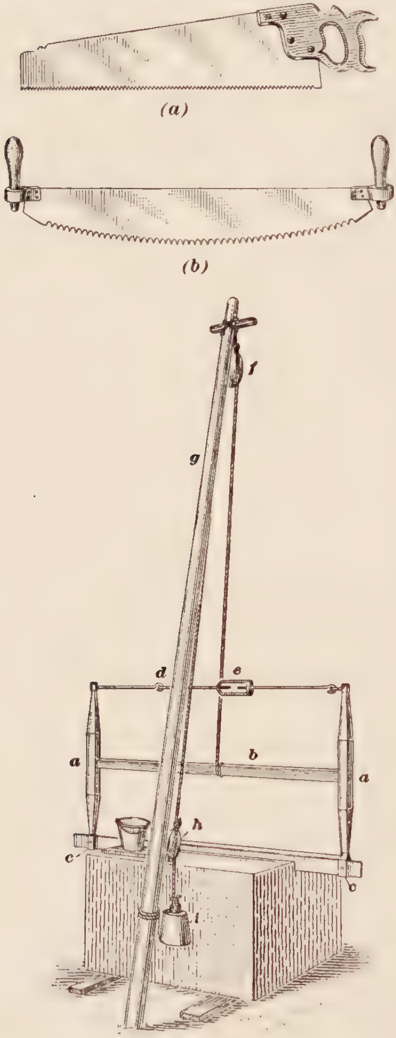
FIG. 3

a quadrant bar, so that the points can be fixed at any distance apart.

The **beam** (*e*) of wood or iron has two compass points of bronze or steel, which can be moved to any position desired and then fixed with screws. The beam is also called a *trammel*. It is used for curves of a larger radius than can be set out with the compass.

58. **Saws Worked by Hand.**—In Fig. 4 are shown the saws worked by hand. The **hand saw** (*a*), about 28 inches long, is used for cutting soft stones.

The **double-handed, or cross-cut, saw** (*b*) is worked by two men. It is a thin sheet of steel, 5 to 6 feet long, having the lower edge curved and toothed, and with a wooden handle at each end.



(*a*) (*b*) (*c*)
FIG. 4

The **frame saw** (*c*) is used for cutting large blocks of stone. The blade is a sheet of steel with blunt edge, about 4 inches wide, $\frac{1}{10}$ inch thick, and about 3 feet longer than the stone to be cut; it is fitted into a wooden frame. The frame has two ends *a*, and a stretcher piece *b*, and the blade is fixed by means of two steel pins *c*, the upper extremities of the frame being held together by a wrought-iron rod and couplings *d*, which can be tightened up by means of a union screw *e*. To work this frame a cord is fixed to the stretcher piece *b*, passed over the pulley *f*, secured to the pole *g*, and the lower end of the cord fixed to the second pulley *h*. A second cord is passed over the pulley *h*, one end of which is secured to the pole *g*, and from the other a weight *i* is suspended, which will almost counterbalance the weight of the saw and frame. This arrangement allows the frame to be drawn to and fro without ever escaping from the effect of the

balance weight, and the cutting action is assisted by coarse sand and water fed into the cut.

59. Machine Tools.—Besides the hand tools just described, there are many machine tools employed to prepare the stone for the finer treatment to be given by hand work. These include *saws, cutters, planers, lathes, grinders,* and *polishers.*

The saws are either drag, circular, or band saws, and each consists of a thin sheet of steel having blunt edges. The drag saw has a forward-and-backward movement, the cutting being done by the aid of sand and water, or chilled cast-iron shot, fed into the cut. The operation of the others is similar, except as to the manner of driving. The cutters are used on the rough stone to somewhat reduce the inequalities and also to run mouldings. Cutters and planers are made on two principles: one kind is used for homogeneous and tough stones, free from grit, etc., which are dressed by machines resembling those used for iron and steel; and the other is for hard brittle stones whose structure necessitates a treatment resembling that employed in hand dressing. The lathe is used for turning columns, balusters, and circular work generally. From the cutter and planer the stone goes to the grinder and polisher, which are practically alike, differing only in the fineness of the surface that they are capable of producing. Pneumatic chisels are also used for lettering, carving, and moulded work. The polisher consists principally of a circular horizontal table on which the stone is fastened, the face to be polished being always turned upwards. This table with the stone revolves about a central vertical axis, while a non-revolving metal plate, vertically adjustable, is pressed on the stone. Sand and water, or chilled cast-iron shot, sludge, and putty powder, are supplied between the plate and the stone, whose surface is thus abraded until the proper degree of smoothness is attained.

STONE CUTTING

60. Methods of Cutting.—Granite blocks are roughly squared into suitable sizes by nicking a line about the stone and sinking small holes about a foot apart with a tool called a *jumper,* into

which holes are placed steel wedges and feathers, as shown in Fig. 1; these are tapped in succession with a hammer until, the stress becoming too great, the stone splits through on the required line. Softer stones are split in a similar manner with small iron wedges, but the holes are cut with a punch or small pick, and not jumped as in granite.

61. Stone Dressing.—In dressing the stones for a building, a rough block is selected. It should be large enough to contain the required finished size, yet without entailing unnecessary labour and waste. The first process for all ordinary work is to reduce the face to an absolutely true plane. To do this a chisel draught is run on one side and one end of the face of the stone. A parallel straightedge is then laid on the draughted end and a similar straightedge is held at the other end in a line with the side chisel draught, and shifted till the two coincide exactly. The line of cutting is then drawn on the stone and chisel draughted, the straightedges being again applied to see if these two draughts coincide. If they do not, then one or other must be cut till they do. Care must be taken that no part of the irregular stone face is below the level of this plane. Additional draughts are then worked across at short intervals, and frequently tested with the straightedge. The remaining surface is afterwards reduced to the same level, and should then form a perfectly true plane if the work has been properly executed. After this has been done the beds are next worked in one plane surface, and the ends squared or jointed at right angles to the face of the stone, so that the joints may be true and the beds have an equal bearing all through.

FINISH OF STONEWORK

62. Stereotomy.—The art of making patterns, or templates, to which a stone is to be cut to fill a certain place in an arch or other complicated piece of stonework, is called **stereotomy.** The architect makes a drawing of the intended stonework, showing where the joints in the face are to be worked, and the stonecutter then details each block and cuts it to fit exactly with the others. For the purpose of presenting a pleasing appearance,

the face of the stone is dressed or finished in many ways, according to the class of work or style or architecture in which it is to be used.

63. Rock-Faced Work.—In Fig. 5 are shown **rock-faced,** or **pitch-faced, work** and the method of using the pitching chisel. The face of the stone is left rough, just as it comes from the quarry, and the joints, or edges, are *pitched* off to a line, as shown at *a*. As very little work is required for this finish, rock-faced dressing is cheaper than any other kind, especially when granite or hard sandstone is used.

FIG. 5

Examples of rock-faced stone are shown in Figs. 6 and 7. Fig. 6 is a good specimen of *squared and snecked rubble,* while Fig. 7 shows the general character of *coursed rubble.* The different methods of setting this work are treated in another Section.

64. Margins.—Building stones are often faced an inch or more from their edges. This dressed strip, which is shown in Figs. 9, 10, and 16, is known as the **margin,** or **draught line.** On soft stone this margin is cut with a chisel, but on extra hard stone such as granite, it is usually cut with an axe, or peen hammer, in which case the surface would be plainer than the chiselled work and without the well-defined parallel channelling. The margin, or draught line, serves the purposes of emphasizing the angle and the joint by contrasting the marginal plain surface with the rougher cut work in the centre of the stone, and of giving a plain surface on which to work the angle of the joint, thus making a more true and accurate edge. A pleasing variation is the bevelled margin shown in Fig. 22 ; moulded margins are frequently used in rusticated work, as shown in Fig. 23.

65. Stugged, or Pointed, Work.—A pointed chisel is sometimes

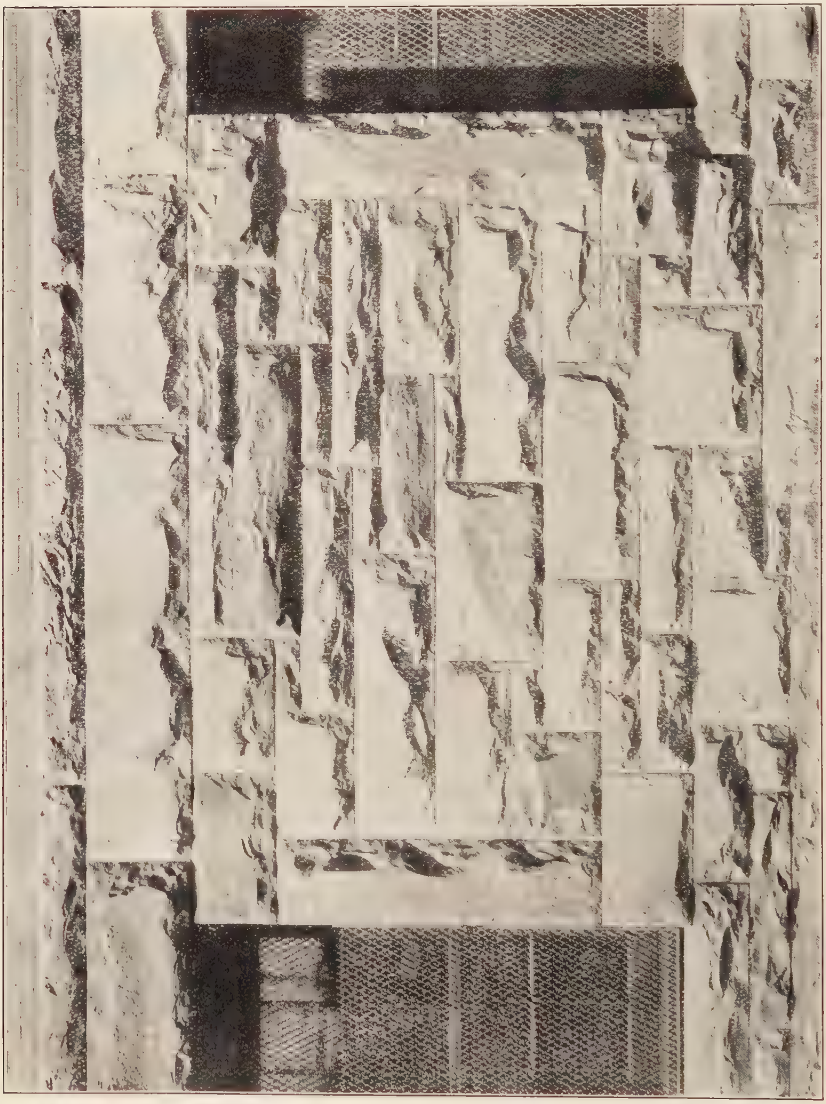


FIG. 6

run over the face of a stone to knock off any large projections.

This work is called rough- or fine-pointed, or stugged, according

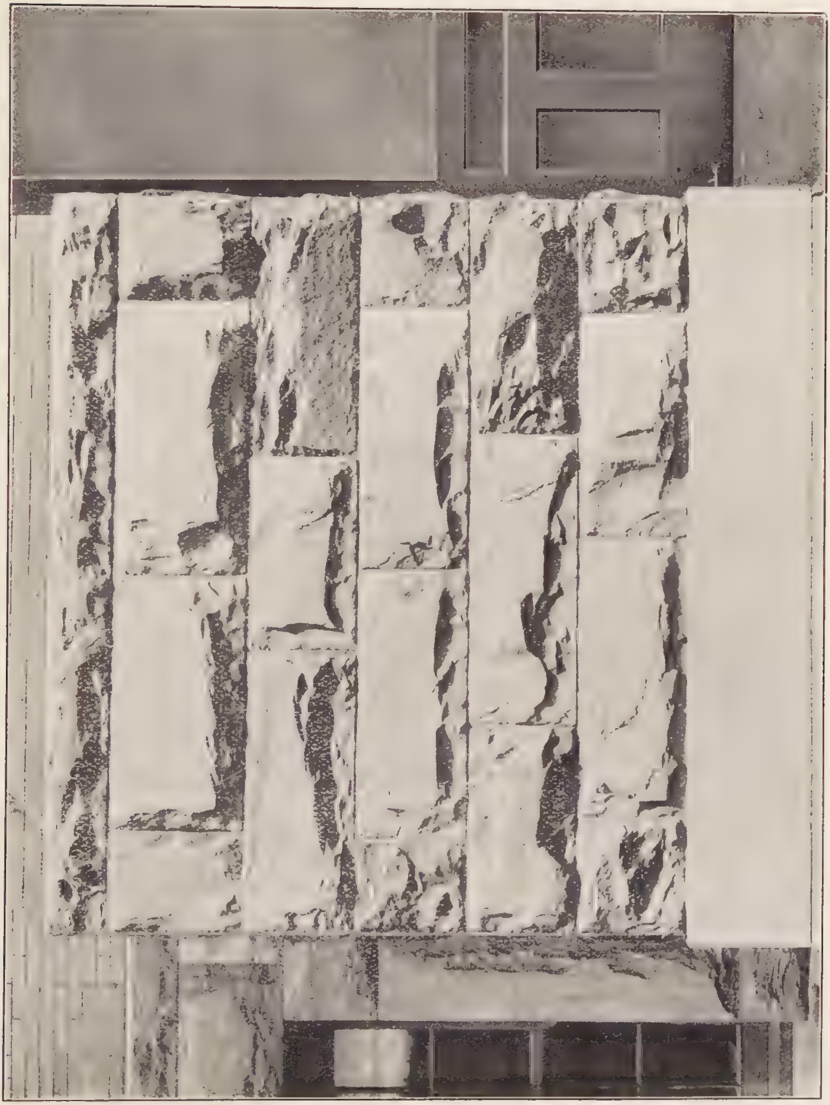


FIG. 7

to the number of times the work is gone over. In Fig. 8 is

shown an example of rough-pointed work, while in Fig. 9 is shown an example of fine-pointed work.

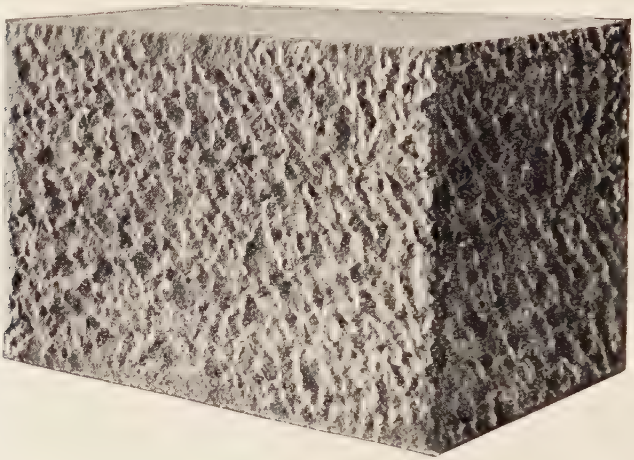


Fig. 8

66. Tooth-Chiselled Work.—One of the cheapest, but less

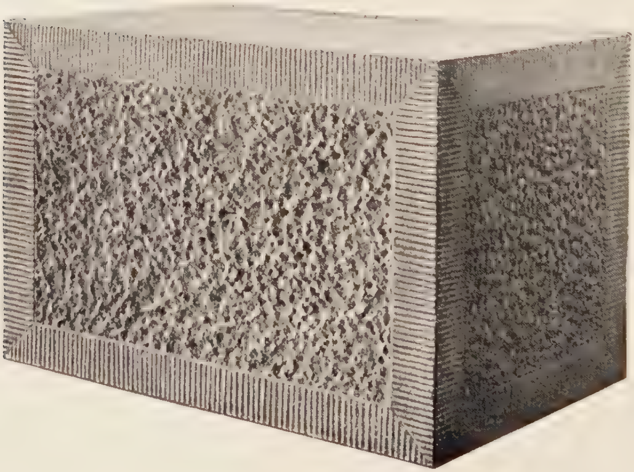


Fig. 9

common, methods of working stone is known as **tooth-chiselled**

work, which is done with the tooth chisel. A surface resembling stugged work, but not so regular, is thus obtained.

67. **Broached Work.**—Fig. 10 illustrates what is known as **broached work.** In this kind of work the stone is dressed with a point, so as to leave continuous grooves over the surface.

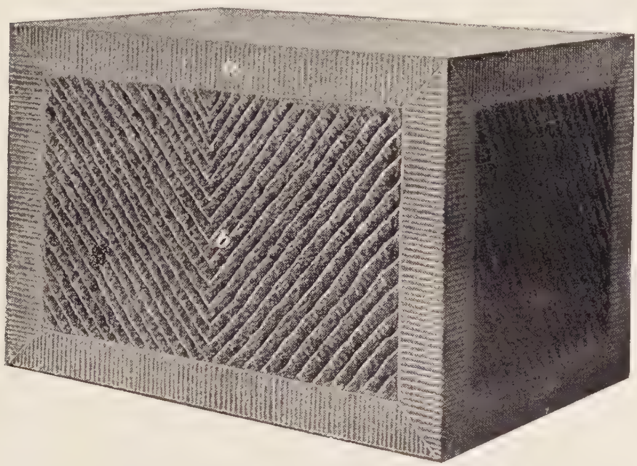


Fig. 10

At *a* is shown the margin, or draught line, and at *b* the broached centre, which is cut in opposite directions in order to illustrate right- and left-hand broaching. Horizontal broaching gives a pleasing effect in ashlar work.

68. **Tooled Work.**—For **tooled finish,** a tooth chisel from 3 to $4\frac{1}{2}$ inches wide is used, and the lines are continued across the width of the stone to the draught line, when one is used. When well done, this work makes a very good finish for soft stones.

69. **Droved Work.**—**Droved work** is formed with the broad tool in regular lines across the width of the stone. It is one of the commonest methods of dressing freestone, and when well done it has a fine appearance. There are two general classes of this work; namely, *hand droved* and *machine droved*, the former being

shown in Fig. 11, and the latter in Fig. 12. Machine-droved

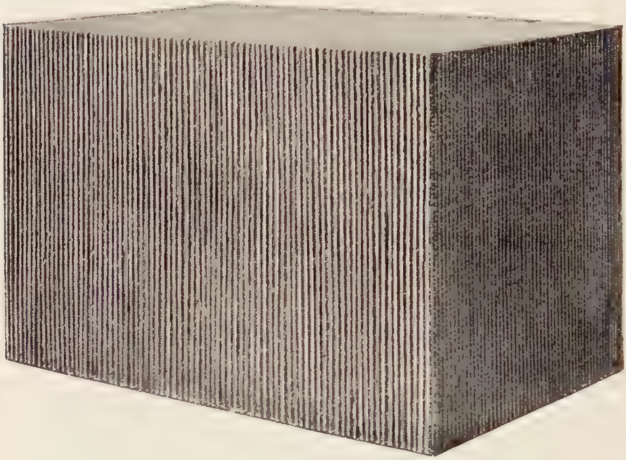


Fig. 11

work, it will be noticed, is more regular, and at the same time

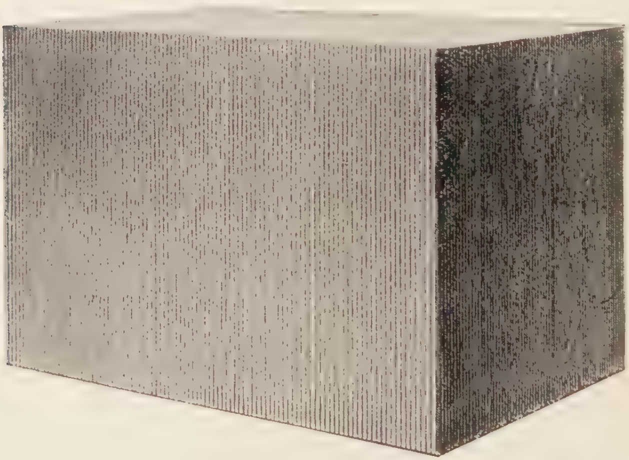


Fig. 12

the cuts are a little deeper, although this is hardly apparent from the illustration. For a large quantity of cutting, machine

work is cheaper than hand work, but is not so pleasing in appearance.

70. Scabbled Work.—A good example of **scabbled work** is shown in Fig. 13. It differs from droved work in being done diagonally, without margins, the whole surface being dressed alike.

Fig. 13

71. Backset Work.—In Fig. 14 is shown a common method of dressing quoin stones and reveals for rubble-faced work and rough-cast work, known as **backsetting.** The face on each angle, generally about 6 inches broad and droved, projects about $\frac{5}{8}$ inch beyond the remainder, which is usually stugged or broached, with margins. This method gives greater prominence to the corners and reveals of a building.

Fig. 14

72. Crandalled Work.—In Fig. 15 is shown **crandalled work,** which, when well done, gives the stone a fine, pebbly appearance. This finish is very effective, but is not very common in the British Isles.

73. Rubbed Work.—Sandstones and most of the limestones

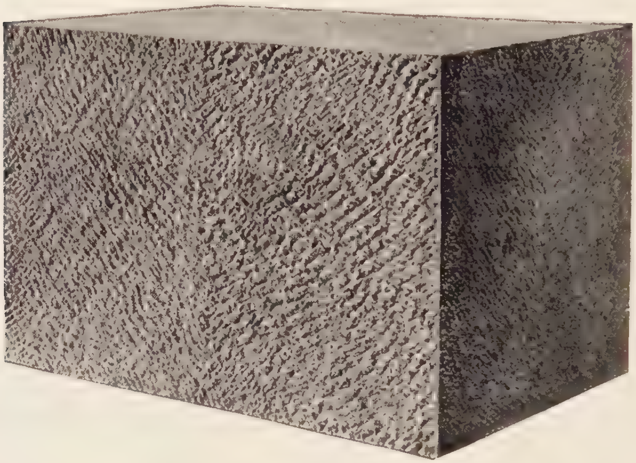


Fig. 15

are often finished by *rubbing* their surfaces until they are

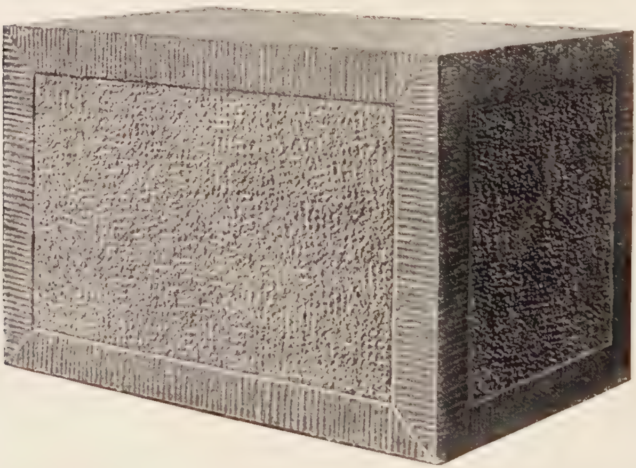


Fig. 16

perfectly smooth. By continuing the rubbing long enough, granite, limestone, and marble can be given a beautiful polish.

Rubbed work is finished either by hand, using a piece of soft stone with water and sand, or by a machine, which performs the same operation. If the rubbing is done soon after the stones are sawn into slabs and are still soft, it is cheaply and easily performed, as the sawing makes the face of the stone comparatively smooth.

74. Bush-Hammered Work.—In Fig. 16 is shown the finish of a stone after having been **bush-hammered,** which leaves its surface full of points; this makes a very attractive finish for

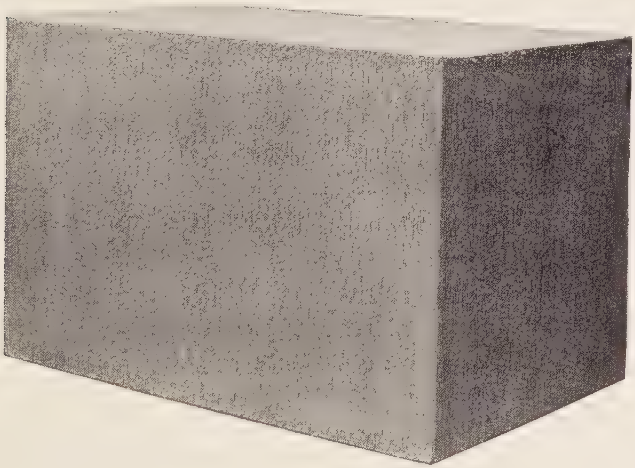


Fig. 17

hard limestones and sandstones, but should not be used on the softer kinds.

75. Patent-Axed Work.—A stone finished by a **patent axe,** which is generally used on granite and hard limestone, is shown in Fig. 17. The stone is first dressed to a fairly smooth surface with the point and then finished with the patent axe. The degree of fineness in the finish is determined by the number of blades in the axe, the usual number being eight or ten. The axe may be used instead of the patent axe, but much more time is required to obtain an equally good finish.

76. Vermiculated Work.—In Fig. 18 is shown a stone having a somewhat elaborate finish, which is known as **vermiculated** from its worm-eaten appearance. Stones so cut are used principally as quoins and in base courses. Owing to the cost, this dressing is not often used, except for very expensive work.

Fig. 18

77. Rusticated Work.—The method of facing a wall with blocks of stone of rough surface, laid in courses, is known as **rusticated work.** Examples of rusticated work are illustrated in Figs. 19 and 20, the former showing the stones with sharp edges and the latter the stones with rounded edges. The joint should be emphasized by bold sunk grooves and always be at the upper edge, as shown at *a* in each illustration, as it is more protected from the weather when in this position. If the joint were placed at the lower edge, rain-water would lie on the lower horizontal surface and be liable to work its way back into the joint. The projection above the joint throws a heavy shadow at this point and strongly emphasizes the courses. It should be remembered that the inner face of the groove is the true face of the wall and that the rough blocks should be considered as projections.

The height of the groove should bear some simple proportion to the total height from joint to joint, and should not ordinarily be less than one-sixth of that height. The depth of the groove should be about two-thirds of its height if the edges are square ; if the edges are rounded, as in Fig. 20, the depth should be equal to the height. The grooves are sometimes formed by **V** joints, wherein the edges of the stone are chamfered or splayed. Some-

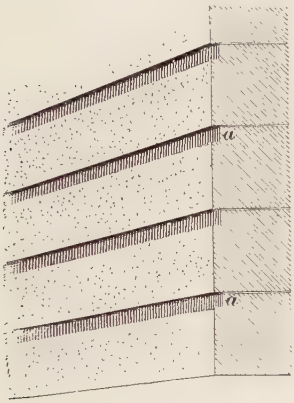


FIG. 19

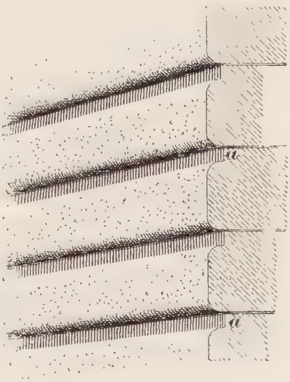


FIG. 20

times the edges are moulded with a cyma or ovolo, the joint in this case coming exactly in the centre, and sometimes the joint is not emphasized at all, as in Fig. 24. Rusticated masonry is sometimes laid with close vertical joints, but is more frequently laid with the vertical, as well as the horizontal, joints rusticated. The latter method gives the better effect when the stones are of good length, as shown in Fig. 21.

78. Rusticated work is used in massive buildings, usually for lower stories, as shown in Fig. 21, where a ground floor window with semicircular head is shown in a heavily rusticated wall. The plain moulded string course and plain base give relief to the heavy rusticated wall surface, which would have appeared overpowering had it been all treated in a similar manner. Great care is necessary, when setting out the keystones of an arch in rusticated masonry, that the centre lines of all the joints between

Fig. 21

each block run to the centre from which the curve of the arch was struck, as otherwise the irregular shapes of the arch stones will be much emphasized by the rustication. This heavily rusticated ground-floor story forms a heavy base treatment strong in shadowed joints, on which is placed the lighter and more ornate upper stories, where the joints are close or, if rusticated, very much smaller than those below

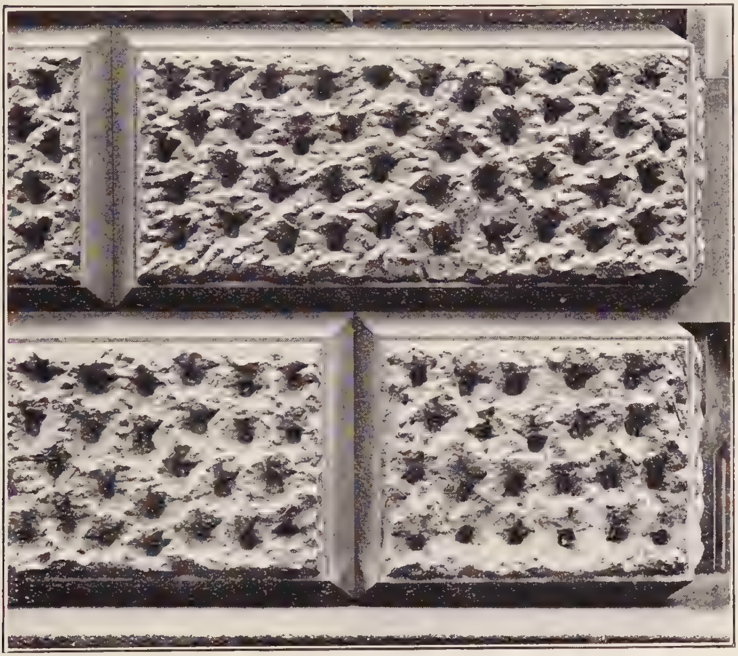


Fig. 22

The surface of rusticated stonework is usually dressed in such a way as to give a rough appearance, as previously described, and as shown in Figs. 22, 23, and 24. Fig. 22 shows to a larger scale the treatment illustrated in Fig. 21. It is a form of rustication much used in building, the blocks having **V** joints between them, emphasizing, by the deep shadows thus given, the massive appearance always appertaining to a wall treated in this way. In Fig. 23 is shown quite a different treatment of a rusticated

face, where instead of a **V** joint between the blocks a rounded

FIG. 23

FIG. 24

or ovolo moulded joint is made, giving a somewhat softer

appearance, although the sharper and more pointed appearance of the face work gives very good and varying shadow effects. The form shown in Fig. 24 is that when worked without deep-set joints between the blocks, but has not such a pleasing effect, looking far less geometrical and workmanlike. The face work, when viewed in a mass in a large wall surface, is not nearly so effective as the finish shown in Fig. 21. These surfaces form a pleasing contrast with the plainer surfaces of the stones above Good examples of rusticated masonry are to be seen in the Italian palaces of the Renaissance period.

CARVED WORK

79. In this Section, the preparation or cutting of stone surfaces has been taken up, and thus far has included rough rock faces and dressed faces, such as fine- and rough-pointed, patent-axed, vermiculated, etc. The final step in the elaboration of stone is **carved work,** two examples of which are shown in Figs. 25 and 26. This requires more skill than common surface finishing, and in fact is an art requiring the skill of the sculptor. Carving is done both at the building, from scaffolds, and in the shop. Models in clay are frequently prepared, and plaster casts are made from these. The expert carver can reproduce the plaster model in stone with wonderful accuracy.

It is important when giving instructions to the mason to see that sufficient stone is left for the carver **bossed out,** or **boasted,** as it is termed, that is, left projecting in a rough way ready for the carver.

As a rule, carving should be done after the stone is fixed in position, otherwise it is liable to be damaged during the process. Carved mouldings must be spaced out and carved after fixing. Capitals of columns attached to or very near to walls may be carved before fixing, if, from their position, carving afterwards would be difficult.

The softer stones, being more easily worked, are more generally used for carving, as the expense is much less than when the granites and harder sandstones are employed, but for all such work the stone should be of the best and most durable description.

Fig. 25

Fig. 26

80. The scale and the minuteness with which carving should be executed depends on its height from the point or points at which it will be seen. Work that will be close to the eye of the observer should be carved out in great detail and fineness if the texture of the stone will permit, while work at some height from the eye should be bold and coarse in treatment to be effective. This latter point is often overlooked, and minute carving, beautiful in itself when viewed at close range, becomes a hazy maze when placed at such a height that its detail is practically lost.

81. Of all the difficult work that a carver has to undertake on the stonework of a building, undoubtedly the most difficult is that in which figure work enters into the composition. The ordinary carved mouldings in a cornice or string course are quite simple when compared with the carving of the human figure. Figs. 25 and 26 show examples of carved figure work in conjunction with an entrance doorway. It will be noticed that in Fig. 25 is shown the rusticated wall surface surrounding the doorway, a detail of the finish of which is shown in Fig. 22. For the general carving on the face of the doorway shown in the shields and swags, the stone would be left rough on the face and **boasted,** as described in Art. **79**, for the carver to finish on the building. Great care is necessary in the finish of this work, which, being at the ground level, can easily be inspected. The carved moulding to the curved pediment would be done by the carver at the same time as the shields, the particular type shown here being called the *egg-and-tongue* enrichment, which is much used in Classic and Renaissance architecture. It is deeply undercut to give good shadows, especially in the position shown where it is already in shadow from the projecting mouldings of the pediment. The carved figures, as also those shown in Fig. 26, should only be undertaken by a first-class sculptor, as figures, badly carved, and not true to nature, may entirely spoil an otherwise beautifully designed building. Too much emphasis cannot be placed upon this caution; it is far better to leave all figure carving out of a building than to have it executed in a second-rate manner.

MASONRY

(PART 1)

FINISHINGS AND WALLING

DEFINITION

1. Masonry is the term given to the practice of shaping, arranging, and fixing stones to form the walls and other parts of buildings. It is one of the important branches of the building trades, for if the masonry work is not good the life of the building will be greatly reduced. The province of the mason, while perhaps not so extensive as that of the carpenter, is none the less important, especially in large cities where buildings are so often built with stone, or stone-faced walls.

TECHNICAL TERMS

2. Bond Stones.—All stone walls require **bond stones,** or stones placed at intervals to run through from front to back of the wall. In the case of very thick walls they run from front to two-thirds of the thickness, so as to tie in the various courses of stones across the thickness of the wall and bind the whole together. The courses underneath should be brought to an exact level to receive the stones; otherwise, the weight above may cause them to crack or become displaced. In the case of piers, the stones should be cut to the full size of the pier whenever possible.

3. Template.—If the end of a girder, column, or beam were laid directly on the brick or rubble walls, it would have a tendency to crush the brick or stone. To prevent this crushing, a

bearing stone, called a **template**, is placed beneath the end of the girder or beam so as to distribute the weight over a larger area. The area is governed by the load to be carried, but a template should always be of granite or hard laminated freestone. The usual rule is that the thickness of the stone should be one-third of the smallest surface dimension, except where very large stones are used, but the least thickness should be 4 inches. It should be too large rather than too small. When a timber beam rests on the template, it is advisable to form a recess by placing a flat stone above the end of the beam, so that the wall will rest on the stone and not on the wood; otherwise, when the wood shrinks, the settlement may cause cracks in the wall. This arrangement also allows for free circulation of air to the timber and tends to prevent dry rot. The edges of the template that are exposed to view are generally dressed, and the stone may, if required, be corbelled out beyond the wall face. Templates under columns or stanchions often require holes sunk in them for fixing bolts through the bases to prevent lateral movement. In such a case, a wooden template or mould must be made and the stones worked from this, so that the holes may be cut in the exact positions.

4. **Cover Stones.**—When a beam, whether of wood or of iron, has to carry a wall somewhat broader than the beam, **cover stones** from 3 to 4 inches thick, in fairly long lengths, and the full width of the wall are used. These are roughly dressed and generally bedded in cement on top of the beam or joist.

STONE DRESSINGS

5. **Definition.**—The term **stone dressings** is used to describe the dressed and cut stonework used in a building for ornamental purposes. It includes any such work as quoins, jamb stones, lintels and sills, corbels, string courses, cornices, moulded copings, columns and entablature, tracery, etc., but does not include ashlar. The stones for such work should be of good quality and have the beds closely dressed and the ends square and properly matched. The faces may be pitched off, but all weatherings,

soffits, etc., should be cut or rubbed. When a brick building has stone dressings, great care should be taken to have the dressings of the proper depth, agreeing with the depth of a certain number of brick courses, so that it will not be necessary to split the courses of brick below or above, for such a procedure would spoil the appearance of the building.

6. Quoins.—The corner stones of a wall are known as **quoins,** and should bond with the work on both faces of the wall. They are often dressed differently from the other stones in order to make them more prominent. Quoin stones should always be equal in size to the largest stone used in the wall; otherwise, the effect of strength and solidity that they are intended to produce will be lost. Sometimes the quoins in a rubble-stone wall are built of brick. Fig. 1 shows an example of stone quoins bonded on both faces to ashlar walls, *a* being projecting plain quoins, and *b* quoins emphasized by margins and self-facing.

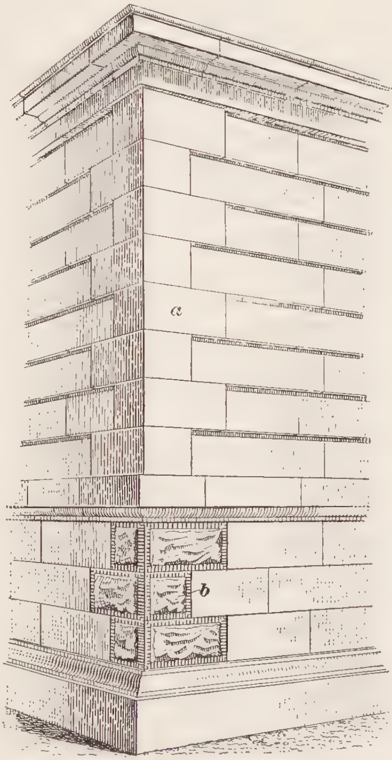


FIG. 1

7. Jamb Stones.—The stones in the sides of a door or window opening are called **jamb stones,** and the stones forming the inside angle are sometimes termed **scuntions.** Fig. 2 represents cut stone jambs in a rubble wall: *a* shows the jamb stones bonding into the wall transversely; *b*, those bonding longitudinally; *c*, the stone window sill; *d*, the rubble wall; and *e*, the

scuntions. Occasionally, when stone piers or pilasters are built

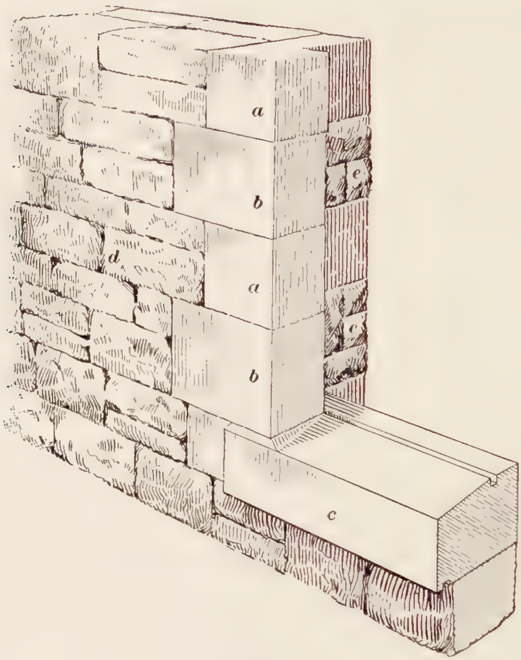


Fig. 2

on the outside of a building, the windows are recessed so that

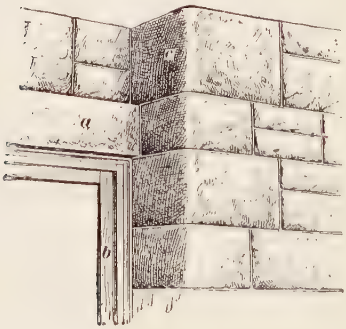


Fig. 3

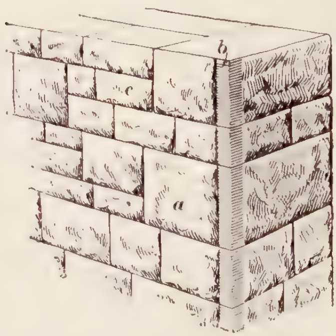


Fig. 4

the projection of the sills and lintels will not be so noticeable. This is shown in Fig. 3, in which *a* shows the lintel ; *b*, the sash ;

and *c*, one of the jamb stones. Jambs and quoins are often finished with a draught, or angle line, especially when the softer stones are used. Fig. 4 shows this method of finishing: *a* indicates the quoin or jamb stone, as the case may be; *b*, the angle draught; and *c*, the squared and snecked rubble wall.

LINTELS

8. A **lintel** is a stone fixed horizontally across an opening to carry the wall or other weight above. It may consist of a single stone, which may or may not require that some of its load be removed by means of relieving arches or steel; or it may consist of several stones joined in some manner and used in conjunction with some method of relieving the direct weight on it.

As a lintel must resist bending stress, it should be a strong, tough stone having an ample cross-section. The ends of the lintels should not be built into the walls more than is necessary to give sufficient bearing; 6 to 9 inches at each end is the usual allowance. There should be a little play allowed at each end, so that the lintels can yield slightly without cracking if the walls on either side settle unevenly.

9. **Strength of Lintels.**—A lintel acts as a beam, hence the ordinary beam formulæ will apply. For uniformly loaded beams, the breaking load is found as follows:

Rule.—*Multiply twice the breadth, in inches, by the square of the depth, in inches, and also by the proper constant. Divide the product by the span, in feet; the quotient will be the breaking weight for a uniformly loaded beam.*

Expressed as a formula, this rule is:

$$\frac{2\,b\,d^2\,A}{L} = W$$

in which b = breadth, in inches;
d = depth, in inches;
L = span, in feet;
A = constant;
W = breaking load, in pounds.

The value of the constant A is for granite, 100; for limestone, 83; for marble, 103; for slate, 275; and for sandstone, 60.

If the weight is concentrated at the centre, the breaking load is $\frac{1}{2}W$ instead of W.

When the weight on a lintel consists of a dead load that is not liable to shocks, such as masonry, one-sixth of the breaking load may be taken as safe. If, however, the lintel is subject to live loads of any kind, not more than one-tenth of the breaking load should be taken. In such cases it is better to avoid the use of stone lintels, unless reinforced by angles or beams.

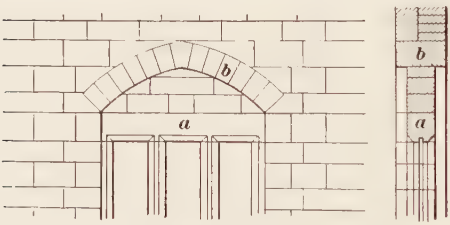
EXAMPLE.—Find the safe uniform load of a sandstone lintel 10 inches broad, 24 inches high, 7 feet long between supports, and uniformly loaded.

SOLUTION.—Substituting in the formula,

$$W = \frac{2 \times 10 \times 24^2 \times 60}{7} = 98{,}743 \text{ lb.}$$

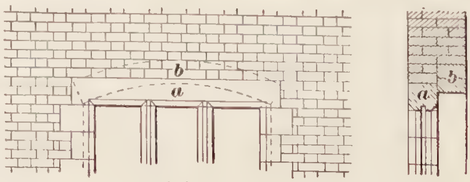
Taking one-sixth of this, gives 16,457 lb. as the safe uniformly distributed load. Ans.

10. When the opening is wide or the load heavy, the lintel must be increased in depth. This may produce a clumsy appearance, to avoid which it is desirable to strengthen the stone or relieve it of some of its load. A simple method of doing this is by using an arch, which may be of almost any style. Fig. 5 (*a*) shows the elevation and (*b*) the section of a relieving arch, *b* going through the wall and taking most of the weight off the head *a*. Fig. 6 shows a method often used. A rough ring arch *b* is built inside the wall and takes some of the weight from the lintel *a* without disturbing the facing. The section through the rough arch is shown in (*b*); and its outline is shown dotted in the



(a) (b)

FIG. 5



(a) (b)

FIG. 6

elevation (*a*). Lintels of various materials are largely used when the head of a window comes near the floor above.

11. Relieving Lintels.—Often when a long lintel is used over an opening, the stonework above the lintel is arranged as shown

Fig. 7

in Fig. 7, in which *a* is the lintel and *b* the **relieving lintel,** or stone above it cut with two radiating joints, as at *c*, *c*. In this way, some of the load is taken off the lintel and transferred to the wall on both sides of the opening. When a lintel extends through

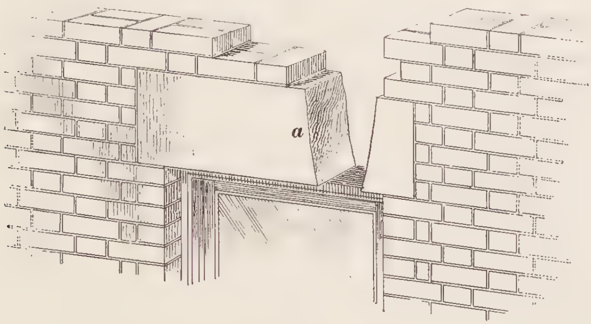


Fig. 8

the wall and is not supported by angles or beams, the strength may be increased, if the stone is stratified, by cutting it in such a manner that the layers will set on edge, as shown at *a*, Fig. 8. This procedure, however, may cause the face of the lintel to flake off if the layers of stratification are thin and not securely joined together.

12. Repairing Lintels.—If a stone lintel should crack and it is not easy to replace it, the lintel may be strengthened by the use of iron beams or angles. When the lintel is of moderate length, it is sufficient to use a piece of angle iron, as shown in Fig. 9, in which *a* is the stone lintel; *b*, the angle iron, which should have its longer side vertical; *c*, a wooden beam to which the interior woodwork is nailed; *d*, the brick wall; and *e*, the window reveal.

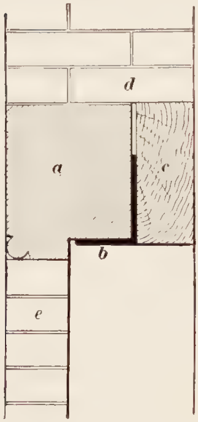


FIG. 9

13. Steel Supports.—When the width of the opening is considerable, stone lintels should be supported on **I** beams. If only the weight of the lintel and wall is to be carried, a single **I** beam may be used, as shown in Fig. 10, in which *a* represents the stone lintel; *b*, the **I** beam; *c*, the beam to which the wood finishings are attached; *d*, the reveal; and

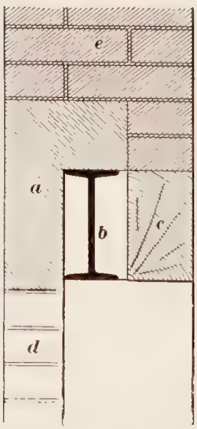


FIG. 10

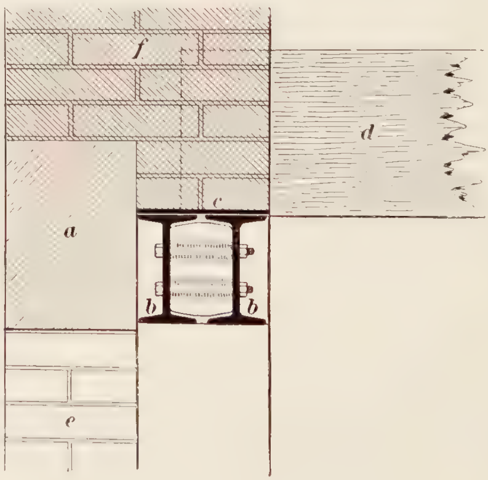


FIG. 11

e, the brick wall. When, in addition to the walls, the floor joists over openings must be carried, it is best to use two **I** beams, as

shown in Fig. 11, in which *a* is the stone lintel; *b*, *b*, the **I** beams, held together by bolts and separators; *c*, an iron plate on which the wall rests; *d*, a joist; *e*, the window reveal; and *f*, the brick wall.

14. When it can be avoided, the best plan is not to support the weight of a wall on both stone and steel or wooden beams, as the deflection of each material is different, making it practically impossible for each to carry its proper share of the load. The weight should preferably be borne by the steel beams alone. The best method of using steel to relieve the weight on a stone lintel is to form a lintel of coke-breeze concrete with a rolled-steel joist embedded in it. This has the further advantages over the method just given in that the steel is protected against fire; besides, joists and joinery may be fixed direct to the lintel, while it gives a face inside the wall in the right plane for plastering. Fig. 12 shows a section of this arrangement, *a* being the stone lintel; *b*, the concrete lintel; *c*, the rolled-steel joist; and *d*, the floor joist.

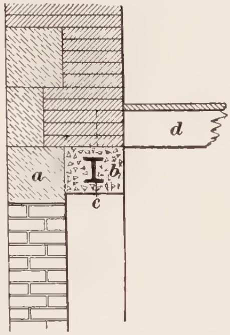


Fig. 12

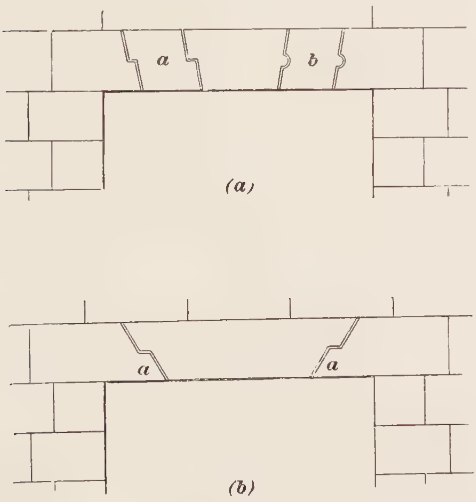


Fig. 13

15. Built-Up Lintels.—As it is sometimes necessary to use a stone lintel 10 or 12 feet long, which is difficult to obtain in a single piece, the lintel may be made in sections. At least three stones should be used, and the joints

should be cut as shown at *a*, *a*, Fig. 13 (*b*), for the stones are then self-supporting. The end pieces must be built into the wall for a considerable length, so as to act as cantilevers supporting the middle section. If such long lintels are used, however, it is better to carry them on **I** beams, as shown in Fig. 10. Another method of arranging the stones in a built-up lintel is shown in Fig. 13 (*a*). The joints shown at *a* are known as *rabbeted;* those at *b*, as *joggled.* It is well, in stonework, to try to place all openings directly above one another.

SILLS

16. In masonry, **sill** is the name given to the stones that form the bottom of the window and door openings in stone or brick walls. They are generally dressed plain or moulded, usually with a projection, but sometimes flush with the wall.

17. **Lug sills** have flat ends, or *lugs*, built into the wall. These lugs should not enter the walls more than 6 inches and should be bedded on mortar only at the ends. If a sill is bedded solid and settlement occurs, it will probably be fractured at the jamb line, as the pier or side walls are apt to settle more than the wall under the opening. The joints under the sills should be filled when the finished walls are cleaned down.

18. **Slip sills** are made just the width of the opening, and are not built into the walls, being put in place after the frame is set. Slip sills are cheaper, but do not look as well as lug sills; besides, there are exposed vertical joints at the ends into which water will penetrate. Any settlement of the masonry is not liable to break a slip sill, and hence they are often used in the lower parts of heavy buildings.

19. All sills should have a bevel, or *weathering*, of about 1 inch to the foot, extending to the back of the reveal, as shown in Fig. 14. They sometimes have a straight bevelled surface the full length of the sill, the brickwork being made to fit the stone. This, however, is not good practice, as such construction permits water, running down the jamb, to enter the joint between

the brick and the stone; the sloping upper face also forms an insecure bearing for the wall resting on it. In Fig. 14 is shown the proper method of cutting the surfaces: *a* indicates the flat end of the lug sill, carrying the brickwork reveal *c*; *b* shows the bevel, or weathering; and *d*, the drip or throating so placed

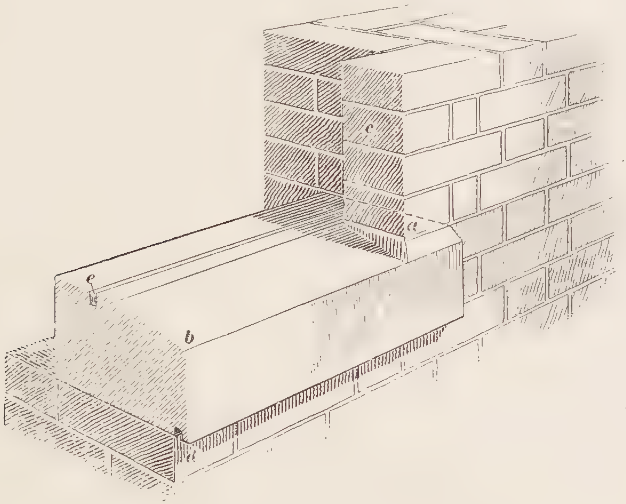


Fig. 14

that water will drip off the face of the sill and not run down the face of the wall; *e* shows the groove which should be made to allow the metal water bar to be inserted between the stone and wood sills, so that water may not drive up between the joint.

STRINGS AND CORNICES

20. Continuous projecting bands of stone on a building, usually moulded, are termed **string courses**; a similar band round an arch is known as a **label, or hood, mould.** In both these cases, the projection from the face of the wall is comparatively slight. Certain moulded bands, considerably larger than strings, from their position and projection are termed **cornices.**

21. Weathering and Throating.—The tops of all string courses and cornices should have an outward and downward

slope from the walls, as shown at *b*, Fig. 15 (*a*), which is known as the **weathering.** If the top is level, rain will collect and, in time, cause the disintegration of the mortar in the adjacent joints and penetrate the wall. On the under side of the cornices, etc., **throatings**, or **drips**, *a*, should be made to prevent rain-water flowing down and discolouring the face of the wall. In certain districts, the local by-laws insist that water from a cornice shall not drip over the public way. When this is the case, a gutter must be formed at the back of the cornice by grooving the stone as shown at *a*, Fig. 15 (*b*), and weathering the cornice backwards to this groove. When cornices are finished in this manner they should be covered with sheet lead to prevent rain-water soaking into the stone and decaying it. The lead should be very carefully dressed over the stone and fitted into the groove *a* to form a gutter from which pipes can be taken at intervals along the cornice, and be connected to the main rain-water pipes of the building. The lead should be dressed over the front member of the cornice as shown at *b*, Fig. 15 (*b*), and should be turned up against the wall and tucked into a groove in the same manner as shown at *c*, so that any water running down the face of the wall

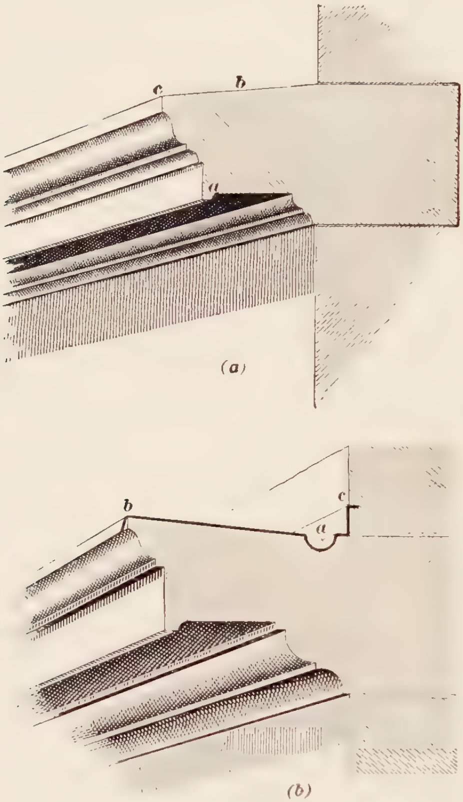


Fig. 15

will find its way into the groove at *a* rather than between the lead and the stone. Great care must be taken, when designing cornices or other projecting members, that they have sufficient bed on the wall, that is, that they project far enough into the wall to counterbalance the tendency to tip over due to the weight of the part projecting. Of course, the weight of the wall over that part of the cornice stone resting on the wall will help considerably to tie it down, but it must not be forgotten that the weight of the portion projecting beyond the face of the wall is very considerable.

22. **Stone Corbels.**—When it is desired to project a portion of the upper part of a wall over the lower, or to provide the extra

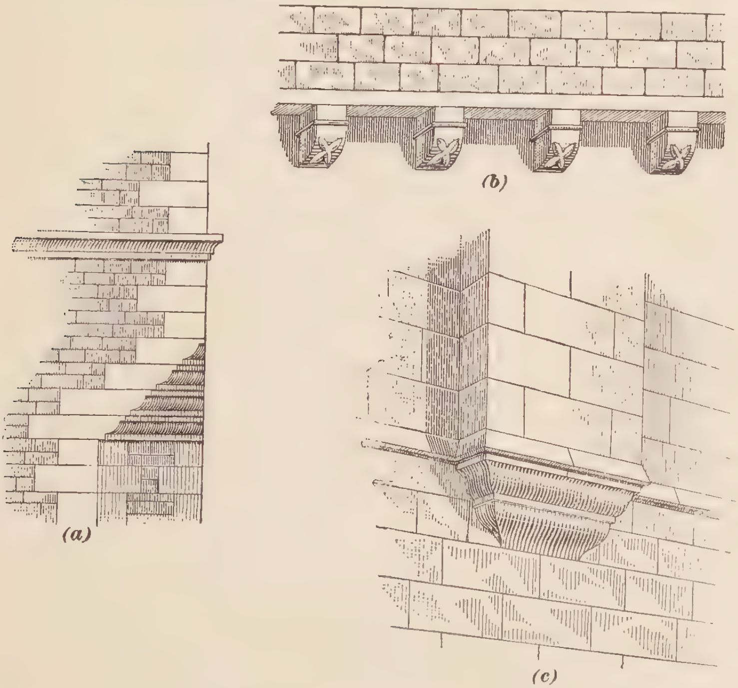


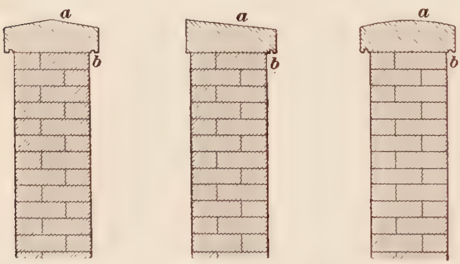
FIG. 16

thickness necessary to form the fireplaces and flues of an upper story, **corbel stones** are used. These are generally of the same size

and strength, but vary in form. Corbels are also used under beams and for carrying wall plates supporting joists and floors, and are a prominent feature in certain styles of architecture. When visible from below, they are generally moulded, though in some cases carved. Fig. 16 (*a*) illustrates the method of corbelling the corner of a building; Fig. 16 (*b*), the method of supporting a projecting course with small corbels, known as a *corbel table;* Fig. 16 (*c*), the moulded corbelling for a projecting chimney.

COPING

23. Coping Stones.—To prevent the rain washing out the joints between the bricks or stone, parapet and similar walls are capped with a wide stone called a **coping.** This coping should be of non-absorbent stone, about 3 or 4 inches wider than the wall. The upper surface should be weathered, as shown at *a*, Fig. 17 (*a*), and should have a throating or drip on the under side, as at *b*. Horizontal coping stones are often clamped together at their ends to prevent their becoming displaced. Other types of coping stones are shown in Fig. 17 (*b*) and (*c*). In (*b*) is shown one weathered only one way; this will need a drip on one side only, while in (*c*) is shown a coping stone with curved weathering.



(a) (b) (c)
FIG. 17

24. Gable copings should be anchored either by bond stones or by long iron ties. A form of coping that is considerably used is shown in Fig. 18, in which *a* is the coping; *c*, the corbel or shoulder; and *b*, the bottom stone, sometimes known as the *skewback*, which should always be well bonded into the wall.

In some cases, the coping is cut in steps, so that each stone will have a horizontal bearing on the wall. This method is

objectionable, however, on account of the increased number of joints. It is well to have long pieces of coping, so as to reduce the number of joints: a common length is 6 feet. A short piece cut as shown at *d*, Fig. 18, and known as a kneeler, should be inserted at intervals to securely bond the coping to the wall.

Gable copings do not necessarily have to be weathered on top, but they should project on both sides of the wall and have a throating at each side, so as to shed the rainwater.

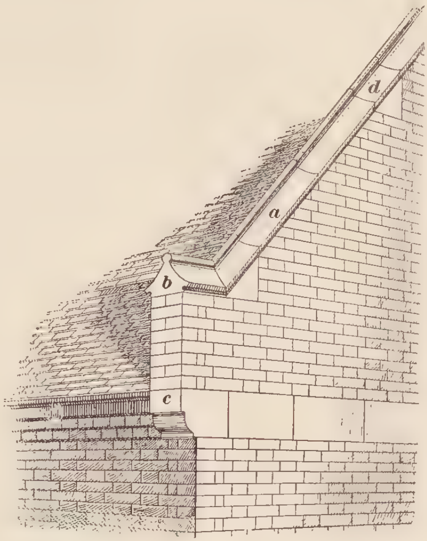


FIG. 18

25. Apex Stone.—Fig. 19 shows an **apex stone** for a gable on a roof of heavy construction. The apex is cut out of a single stone, and is made with a flat bed so as to rest solidly on the end wall. The two faces are grooved to receive the coping stones as shown at *a*, in the illustration. The apex is often secured to the wall by means of iron ties, which are placed inside the building.

COLUMNS AND ENTABLATURES

26. Columns.—A **column** is a long upright body which supports some superincumbent weight. It is constructed either of one stone, in which case it is termed a *monolith*, or of a series of stones fixed one above the other and of some regular shape in section. It is often circular, but just as often hexagonal, octagonal, or of any other geometrical section. It is often used as a method of ornamentation only. In Fig. 20 (*a*) is shown a column *a*, *b*, *c* standing on a pedestal *d*. A column is divided into

three parts as shown, where *a* is the base, *b* the shaft and *c* the capital.

When a column is to be formed of several pieces, the stones composing the different parts should be very carefully cut, having the abutting surfaces between the capital, base, and shaft perfectly plane and perpendicular to the axis of the column, in order that the pressure may be evenly distributed over the entire surface of the joints. For the joints, nothing but cement mortar should be used, which should not be allowed to come within $\frac{3}{4}$ inch of the edge of the joint, in order to prevent the edges of the stones from spalling. **Capitals** and **bases** should, if size permits, be in one piece. If the capital is to be carved, it should be done, if possible, after it is fixed in place.

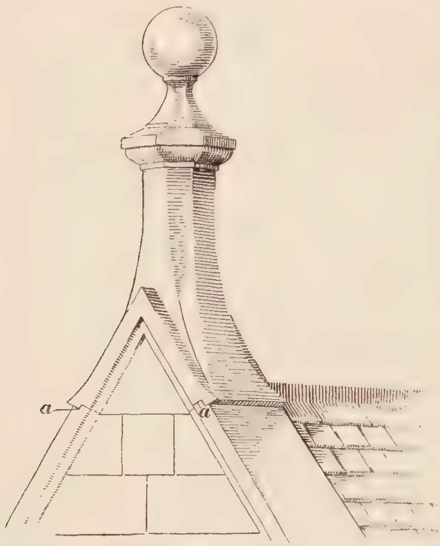


FIG. 19

A column may be either *detached* or *attached*, according to the position it occupies. It is said to be **detached** when it is entirely free throughout its whole section, as shown in Fig. 21 (*a*), where *a* is the column standing free or detached from the wall *b*. When a column is partly bonded into a wall, it is said to be **attached**, an instance of which is shown in Fig. 21 (*b*), where *a* is the column bonded into or attached to the wall *b*.

27. **Entablatures.**—An **entablature** in classic architecture referred to the architrave, frieze, and cornice carried over a column or series of columns, as shown in Fig. 20 (*a*) and (*b*), where *e* is the architrave, *f* the frieze, and *g* the cornice. Above the entablature is shown a **balustrade** *h*, which can be designed

in many styles; the one shown has moulded balusters *i* spaced at regular intervals and stopped between projecting blocks of

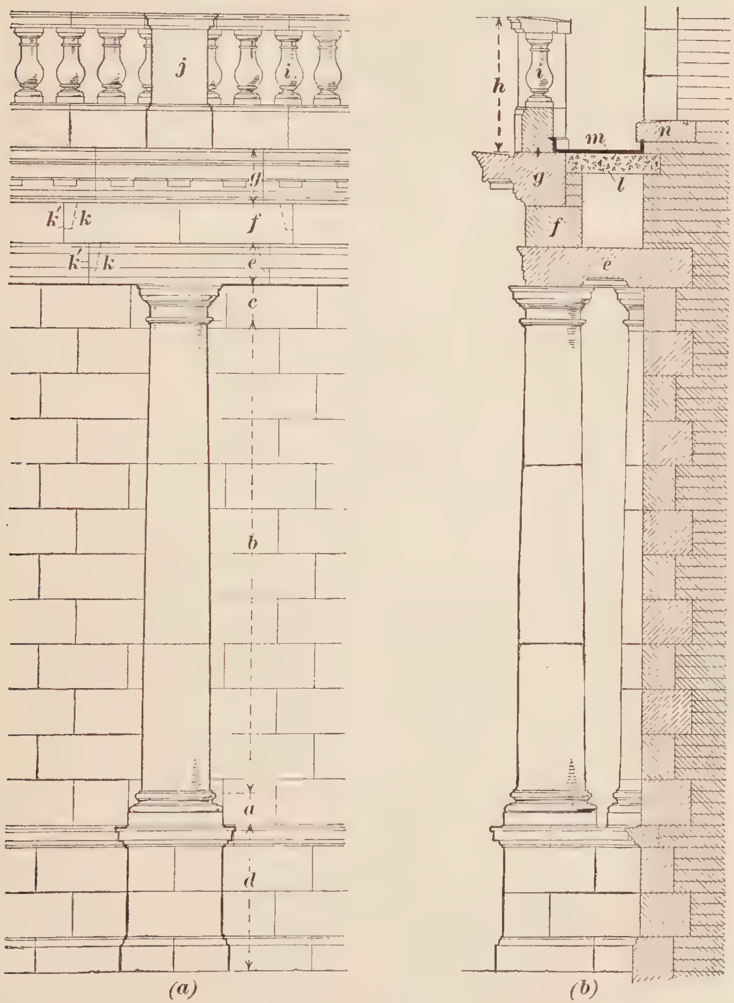


Fig. 20

stone, as shown at *j*, Fig. 20 (*a*). In Fig. 20 (*a*) is shown the elevation and in (*b*) the section through the entablature and balustrade. At *k*, *k* is shown dotted the rabbeted joint to the

stones forming the architrave and frieze, as described for Fig. 13 (*a*) and (*b*), the only difference being that in Fig. 20 (*a*), at *k*, the rabbets in the joint are stopped before they appear on the face of the joint, so that a straight joint as at *k'* shows on the face. At *l*, in view (*b*), is shown the concrete flat behind the balustrade covered with asphalt *m* to keep the wet from entering the wall. At *n* is the stone sill to a window in the main wall of the building.

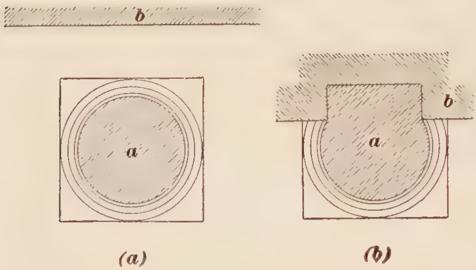


FIG. 21

28. Blocking Course.—A course of stones built on top of a cornice, partly to tail the same down and partly to form a satisfactory finish to the roof, as shown at *a*, Fig. 22, is called a **blocking course.**

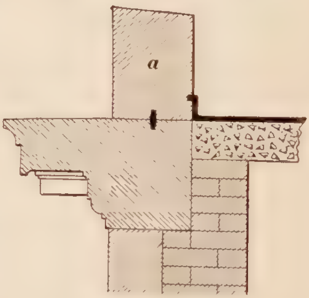


FIG. 22

29. Pediments.—A **pediment** is an architectural feature in classic architecture often of a triangular shape resembling a gable at the end of a building, following the slope of and forming a stop to the roof. It is usually surmounted by a series of mouldings or cornice. A pediment is frequently used as a decorative feature over a door or window opening, or over a portico, quite apart from the outline of the roof from which it was originally derived. In Fig. 23 (*a*) is shown the elevation and in (*b*) the section of a pediment over a window opening, of triangular form, where *a* is the window head and *b* the pediment; but pediments are often formed with curved outline, as shown in Fig. 23 (*c*) and (*d*). The triangular space *c* contained between the horizontal and raking mouldings of a pediment is called the *tympanum.*

TRACERY

30. **Tracery** is the term given to the perforated slabs of stone forming a kind of openwork design showing arches, curves, and flowing lines, often fitted into the openings in Gothic masonry. In elaborate examples, the joints must be arranged and dowelled so that each stone is well supported by those it touches and so that no piece will become loose and fall out. Whenever possible, the plane of the joints should be at right angles to the moulding,

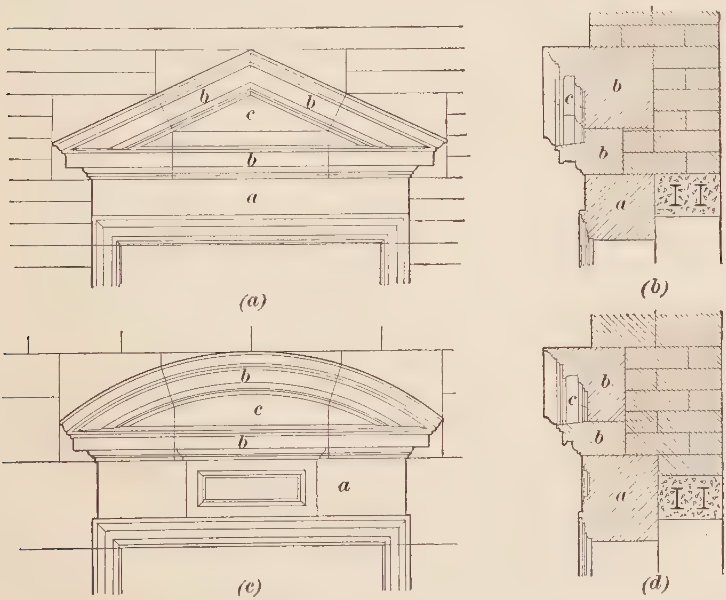


Fig. 23

while rabbets, or grooves, for the glass, when tracery occurs in window heads, must be in a true line. Great care must be taken with the dowels, as they are frequently very difficult to fix.

There are two main divisions of tracery, according to method of preparation of the stone forming the tracery. **Plate tracery** consists of a thin slab or slabs of stone, with openings pierced in same, when intended for a window construction, as shown

in plan and elevation in Fig. 24 (*a*). This was the earliest type and simplest form of tracery. The other division of tracery comprises that known as **bar tracery,** which is much more elaborate in its design. In this form, shown in plan and elevation in Fig. 24 (*b*), the design is made up of comparatively small stones,

FIG. 24

each one just of the correct curve, and fitting in accurately with those next to it. It is of importance that great care be taken in setting out the joints for bar tracery, for the strength of the tracery depends to a great extent on the accurate fitting of each piece.

31. **Diaper work** is a term given to surface carving on stone, as shown in Fig. 25, when arranged in the form of small squares, or some other simple geometrical form which repeats. It is used to give texture and emphasis to certain portions of the wall surfaces in Gothic architecture.

LABOUR

32. **Definitions.**—**Labour** is the term used to describe the work done in preparing stone for a building. The various methods of finishing the face of a stone are described in *Building Stones*, but the labours necessary to bring stones to the shape required by their particular position in a building are the following:

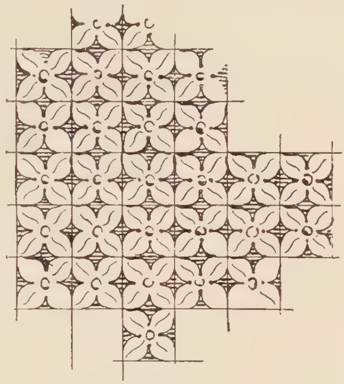


Fig. 25

Self-Faced, or Rock-Faced. The natural broken surface of stone on which no labour or tools have been put, except to bring it to an approximately square form.

Half-Sawn.—The labour of cutting a block by sawing and indicating that the expense of cutting is to be divided one-half to each stone.

Sunk.—Any labour executed below the plane of the surface originally found, such as panels, weathering of sills, etc., Fig. 26 (*a*).

Moulded.—The labour required in forming a shaped profile to the edge of a block, Fig. 26 (*a*). At *a* is shown by dotted lines the original shape of the block before the mouldings were worked.

Rubbed.—The labour required in producing the smoothest face possible; it is generally done by rubbing the face to be finished with a piece of similar stone, adding sharp sand and water, and gradually reducing the quantity of sand.

Polished.—The same as rubbed, and performed in a similar manner, but only on stone sufficiently hard to take a polish, such as marble, granite, etc.

Circular.—The labour required in forming any block into a convex or cylindrical form, such as the shaft of a column when the diameter does not vary, as shown at *a*, Fig. 26 (*b*).

Circular Sunk.—The labour required in forming concave cylindrical surfaces, such as the soffit of an arch or a large hollow

moulding, Fig. 26 (*c*). The dotted lines *a*, *a* show the original shape of the block of stone.

Circular Circular.—The labour required in forming plain surfaces that are convex in all directions, such as the exterior of

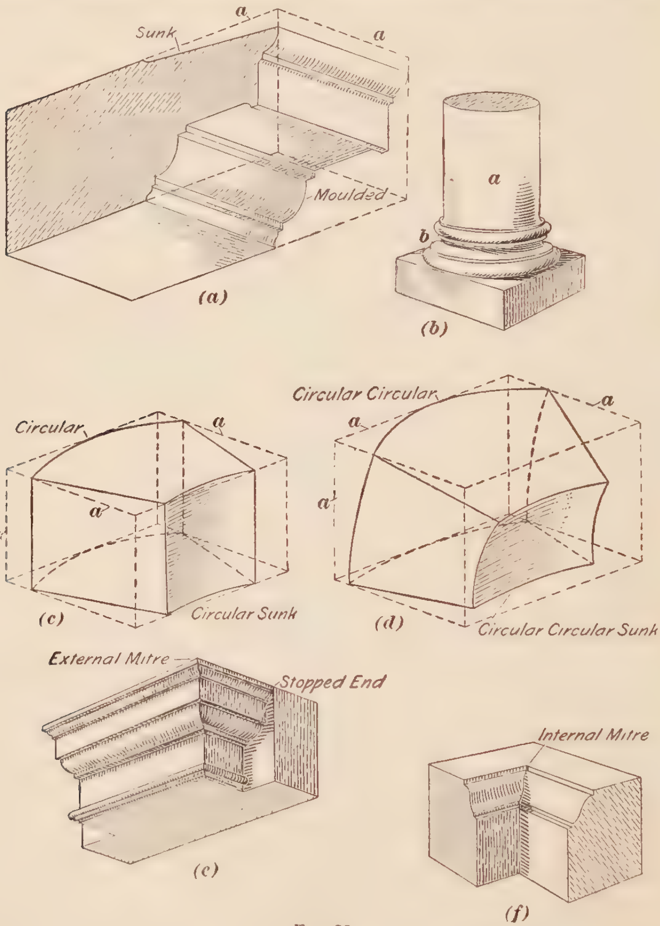


Fig. 26

a dome or a circular column with an entasis, Fig. 26 (*d*). The original shape of the stone is shown at *a*, *a*.

Circular Circular Sunk.—The labour required to plain surfaces that are concave in all directions, such as the basin of a font or

the interior of a dome, Fig. 26 (*d*). Here again the original shape of the stone is shown by dotted lines *a*, *a*.

Moulded Circular.—The labour in forming a moulding on a circular edge, such as a base as shown at *b*, Fig. 26 (*b*), or an arch moulding.

Mitre.—The intersection of two mouldings. **External mitres** are those in which the mouldings intersect at an angle greater than 180°, Fig. 26 (*e*). **Internal mitres** are those in which the mouldings intersect at an angle less than 180°, Fig. 26 (*f*). **Returned mitred stopped,** when a moulding is mitred and stopped by an intersecting plane, Fig. 26 (*e*).

33. Moulded and Enriched Work.—So far, plain stone dressings only have been described, but the judicious use of moulded surfaces and arrises gives beauty and character to a building, and the highest art of the mason is shown in the proper use of such work on wall surfaces. The execution of this work often requires a knowledge of geometry, combined with technical skill ; but however elaborate the enrichment or moulding may be, the stone must be dressed to a regular shape before the mouldings can be set out or the irregular surfaces sunk.

34. Winding Faces.—For skew arches, the soffits of stairs, etc., it is sometimes necessary to dress the stone with a winding surface, by which is meant a face similar to that obtained by the warping of wood. This is done by using one parallel-sided straightedge and one with diverging edges, which will give the twist necessary. The parallel-sided straightedge is placed on a draught on the edge of the block of stone and the other straightedge is applied to the other side, on which a draught has been worked, until the upper surfaces are found to be in line. Draughts are then cut on each end of the stone, connecting the two ends of those formerly cut. The two side draughts are then subdivided into any number of equal parts and straight draughts worked between them.

35. Method of Sinking Mouldings.—In preparing a stone for moulding, a full-sized template of the moulding, accurately formed in zinc, is applied to both ends of the squared and dressed

stone and the outlines scribed with a sharp point. Any well-marked planes that approximately contain the lines of the mouldings are also marked on the ends of the stone. The stone is then reduced, bringing it nearer the shape of the finished form; from these faces the mouldings, if they are close to it, may be sunk direct; but, if necessary, further sinkings must be made, in making and working which the bevel is of service.

When the moulding runs the length of the stone, each successive plane is worked before the moulding is finished, care being taken not to cut below the level of the finished face. The mouldings should be roughly chiselled to near the approximate size and shape, by about $\frac{1}{8}$ inch fuller than finished size, and then cleaned up with narrow and rounded chisels. The straightedge is frequently used to test the accuracy of the long lines. Mouldings on curved surfaces are worked in a similar manner, but the block, after being squared, is reduced to the required curve before sinking the mouldings, for which a face mould is used to mark out the curved block.

STONE WALLS

CONSTRUCTION OF WALLS

36. Stone walling is usually divided into three classes: *rubble*, *block in course*, and *ashlar*. It may be constructed entirely of stone or partly of stone and partly of brick, but both forms require footings, which are often entirely of stone or brickwork. Careful attention must be paid to the bonding, the materials being so used that the individual stones will bond in with those next to them, not only on the face, but throughout the thickness of the wall. Bond stones, as before described, must be carefully inserted and should never be less than two-thirds the thickness of the wall, and the full thickness whenever possible. Rubble walls cannot very well be made less than 18 inches thick.

In walls built principally of small stones, it is desirable that larger stones should be used where angles and openings must be formed, as these are more easily set and plumbed and will bond

with the face work on both sides of the angle. The salient or exposed angle usually has a draught on each face, though the other parts of the exposed face may be worked differently. The inside and outside of a wall should never be built up separately and the centre filled with small stones. Both sides should be carried up simultaneously, and the stones should cross from opposite sides of the wall and overlap as much as possible. The vertical joints should be carefully filled with mortar.

37. Formation of Joints.—In setting dressed angle stones, the joints are usually made somewhat thinner than those for the remainder of the wall; the stones should therefore be wetted to prevent their absorbing the moisture from the thin mortar joints. Even when the beds are irregular and the mortar joints thick, the stones should be wetted in dry and sunny weather.

38. Sizes of Stones.—Being of a brittle nature, the stones in a wall must be properly supported and well bedded in order to prevent their breaking. Extremely long lengths should be avoided, although the length should be greater than the height, especially in ashlar work, on account of the vertical bond. As a certain medium should be observed, the mason will often find it better to break a very long stone into two or more shorter ones even though a compact mass, broken as little as possible, is most desirable in stone as well as in brick walls. However, in setting stones, as steps or sills, it is customary to bed them solid only at the ends, except where they are of very long length, when they should have intermediate bearing, so that when the mortar joint shrinks there will be no danger of the stones being broken by bearing on some obstruction at their middle.

The best stones should be used for piers, jambs, sills, lintels, cornices, string courses, etc., in the order mentioned; and all stones that are longer on the face than on their heights should be so quarried that they can be laid on their natural beds.

39. Setting Stonework.—In erecting stonework, care should be exercised to have the stone set on the natural bed, that is, on the same surface or bed as that on which it was resting in the quarry, with good joints. The bed joints in ashlar work

should be square to the face of the work, and not less than 6 inches wide at both top and bottom. The proper bonding of the walls, especially for ashlar and for dressings, should be given very careful attention, as well as the placing of lintels, copings, wall ties, etc.

In joints on which great pressure comes, the mortar should be kept back from the face, so that the edges of the stones will not be chipped off, while in pointing, the joints should be well raked out and the pointing mortar properly inserted. Many other precautions for the good performance of the work will doubtless suggest themselves.

Whatever may be the quality of mortar used, the wall should contain as much stone and as little mortar as is necessary to form the joint, for the former is the stronger material. In rough walling, if the stones are pressed together until the more prominent angles on their faces come almost into contact, the interstices being filled with mortar, there results better work than if a thick yielding mass of mortar is allowed to remain in the joints. Absolute contact is not advisable in stonework, any more than in brickwork, as the mortar in drying shrinks and may leave the stones bearing only on the projecting angles.

Joints in stonework vary in thickness from $\frac{1}{8}$ to $\frac{1}{2}$ inch; a $\frac{1}{4}$-inch joint is probably the best for ordinary work, while a $\frac{1}{2}$-inch joint should be used for rock-faced work only.

40. Cement and Mortar.—For damp places, stonework should be set with cement mortar, while for dry situations lime mortar may be used. Cement is always preferable, however, for general use.

In work that is to be pointed, no mortar should be placed within an inch of the front edges of the stone, as this saves raking out the joints preparatory to pointing. Sometimes, slips of wood the exact thickness of the joint are set on the edges of the lower course; in setting the stone, the superfluous mortar is pressed out and the stone rests on the wooden slips, which are removed when the mortar is hard. No mortar for pointing is better than pure well-slaked lime mixed with two parts of washed sharp sand. The mixture should be worked until the

mass assumes the consistency of glaziers' putty. The tints of the mortar used for pointing, if it is to be coloured, should be of a shade that will give relief to the blocks and also softly blend with the general shade of the stone; but care should be taken not to make the joint lines too striking, as, by so doing, it imparts to the work a harsh and repellent appearance.

Portland cement discolours most limestones and marbles, and some sandstones. By exercising care, the mortar may be kept from the face of the stone, and the joints may be pointed afterwards with mortar that will not stain. A cement made of plaster of Paris, lime, and marble dust, is sometimes used for setting marble and limestone; it is claimed that this will not cause discoloration.

RUBBLE WALLS

41. Definition.—**Rubble work** is a general term for masonry in which the stones are of various and irregular sizes, and, in most cases, small. It is usual in describing this class of work to add some secondary title to show what kind is wanted. In all cases, the beds of the stones are roughly prepared with the hammer, and sometimes with the chisel and mallet, or the punch. The face of the stones may be dressed differently, generally as best suits the nature of the stone and the cost. Conglomerate and whinstone abound in many localities and are cheap and durable, but do not cut easily. They are often used, with good effect, with cut-stone or brick dressings, or, when good lengths can be had, for rock-faced sills, lintels, and dressings.

42. Field-Stone Walls.—In Fig. 27 is shown a **field-stone wall,** or **dry-stone dyke.** Walls of this kind are built of small, uncut boulders or quarried stone without any bedding or jointing, and, in stone districts, are frequently employed for field fences and rustic-house work. These walls are built thick and tapering in section, usually about 5 feet in height, bonded with long stones in the centre of the height, and coped with the larger stones. Sometimes the copings are set in lime mortar, which adds greatly to the strength and life of the wall; occasionally they are coped with layers of turf.

43. Random Rubble Walls.—Fig. 28 shows **random rubble** masonry, which is much used in country districts. The *quoins,*

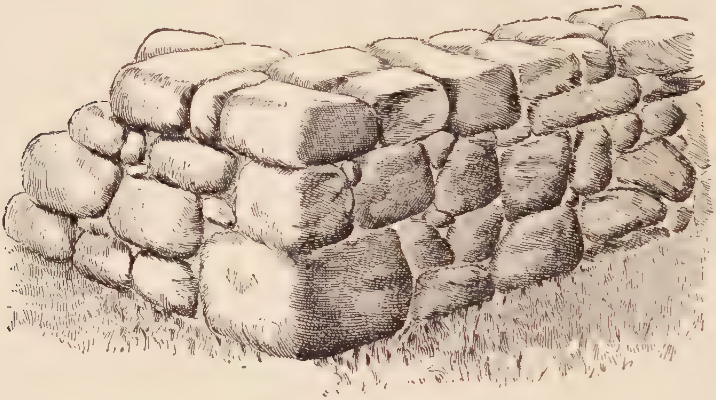


Fig. 27

or corner stones, *a*, are hammer-dressed on top and bottom beds, and may be either cut stone or rock face; the latter harmonizes well when stones similarly dressed are in the body of the wall.

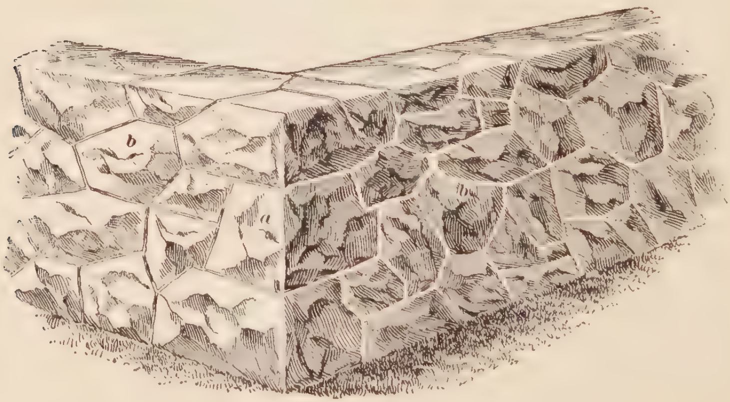


Fig. 28

All joints should be hammer-dressed, as shown at *b*, and no spalls should show on the face, while the mortar joints should not exceed $\frac{1}{2}$ inch in thickness. This makes an effective wall,

especially for country churches, lodges, and other small buildings; but the work is expensive, owing to the labour required in dressing the beds and joints.

44. Fig. 29 represents a better kind of random rubble wall, the stones being of irregular shapes, but roughly squared, without regular beds and joints, and bonded about every 4 or 5 feet, as shown at *a*; the largest and best stones should be placed at the bottom and at the angles, as indicated at *b*, set in alternate courses of headers and stretchers. Such work is generally set

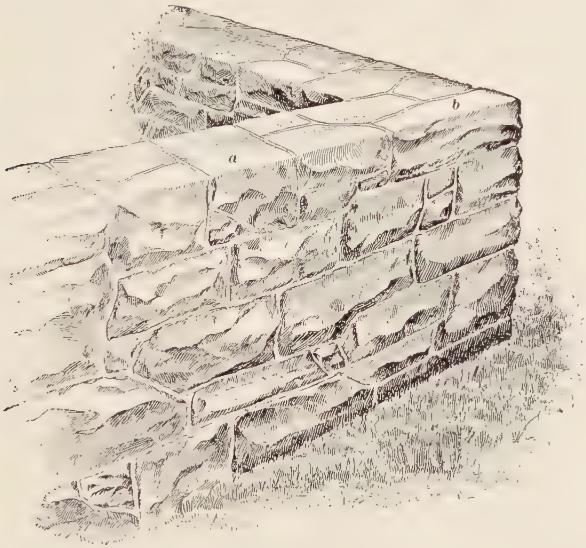


Fig. 29

with beds and joints roughly dressed to fit one another, the stones being set irregularly in the wall in lime mortar and pointed on the face, and the interstices filled with spalls and mortar. If better work is desired, the joints and beds of the stonework should be hammer-dressed. The walls are sometimes flush-pointed and keyed on the joints, or pointed with coloured mortar, showing raised joints.

45. Random Rubble Built in Courses.—Rubble built up to courses, as shown in Fig. 30, is common in some parts of the

country, and consists of rubble built so that, at intervals of from 12 to 18 inches, a true and horizontal bed is formed, set

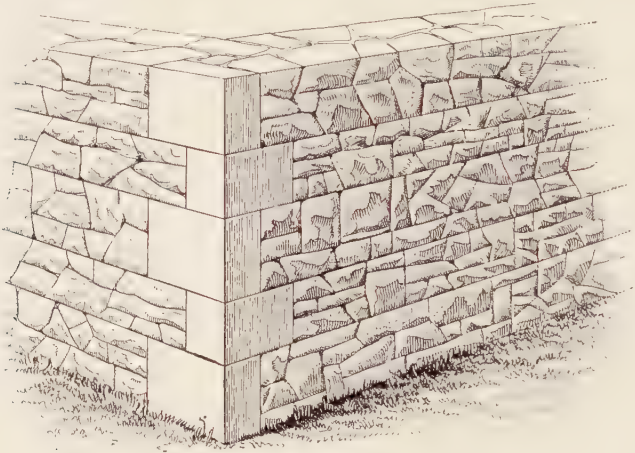


Fig. 30

out to correspond with the corners and dressings. In some cases the wall is built of irregular coursed rubble with bonding

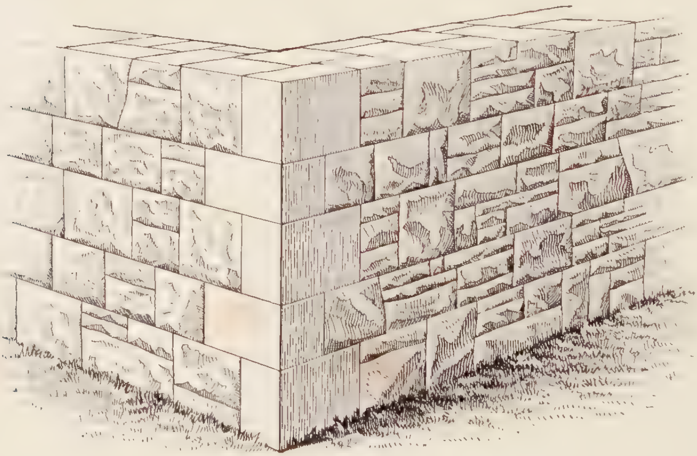


Fig. 31

blocks in each course equal to the full height of the course in which they occur, as in Fig. 31; such work is usually termed

coursed header work, and the headers in such a wall should equal about one-fourth of its superficial area.

46. Irregular coursed rubble, or, as it is more frequently termed, **squared and snecked rubble,** is illustrated in Fig. 32. In this class of work the vertical joints are usually square and the beds horizontal. The latter run through the length of several stones, but not continuous for more than a few feet, and may be broken at any point to fit in a stone of greater depth. *Snecking* is fitting and filling in smaller stones to complete the shallow courses and bring up the beds to a level.

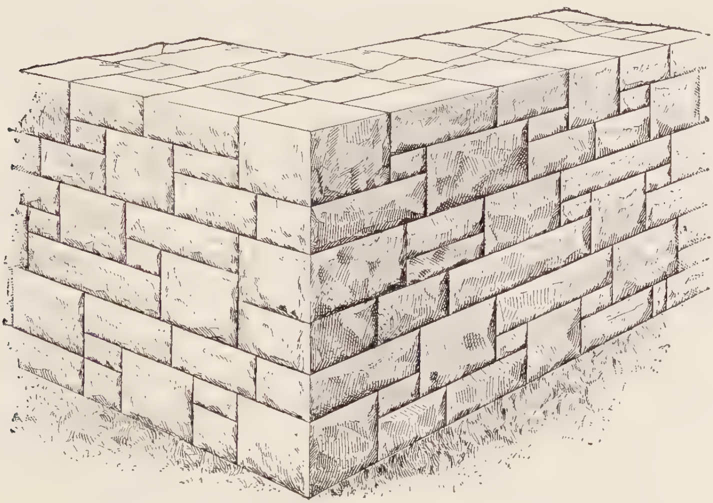


Fig. 32

In regard to the best method of proportioning the blocks and arranging the same so as to produce a harmonious effect, it is first necessary to consider what the various heights of the blocks must be in order to form good longitudinal bond. Assume the lowest heights at 3 inches, as a stone any thinner than this presents an appearance of weakness, and the greatest height at 12 inches, as any stone higher than this looks too heavy for random coursed rubble; the graduations may then be 3, 4, 5, 6, 7, 8, 9, and 12 inches, thus giving eight heights, a variety that, when well arranged, produces a pleasing effect.

If the highest number is taken at the *jumper* or course leveller, the other numbers will agree with it as follows: $3 + 9 = 12$; $4 + 8 = 12$; $5 + 7 = 12$; $6 + 6 = 12$; $4 + 4 + 4 = 12$; and $3 + 3 + 3 + 3 = 12$; or six arrangements.

The next point to be considered is the length of the blocks. The bond, or the lap of the stones over one another, should be, for the thinner blocks, at least 6 inches, and for the thicker ones, 8 inches.

This class of work is more costly than ordinary or coursed rubble owing to the increased labour in dressing and fitting the stones. It is usually rock-faced, but it may be stugged or hammer-dressed. Fig. 33 shows a good example of this class of work, but with some vertical joints bevelled instead of being squared. This, however, is less common and more expensive on account of the extra labour required in dressing and building, but it has a finer and more pleasing appearance.

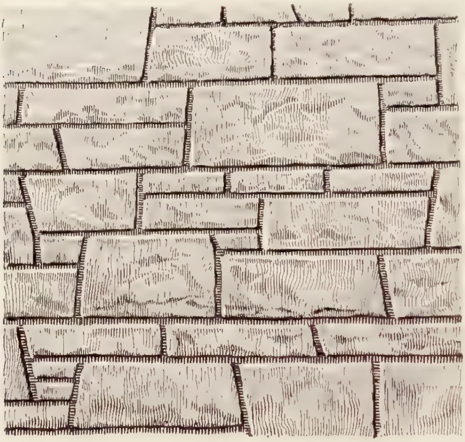


FIG. 33

47. Regular Coursed Rubble.—Fig. 34 shows an example of **regular coursed rubble,** which is used where a more uniform appearance is required and where stones of a fairly uniform size can be obtained. The stones are of various lengths and all the courses are of uniform height. Fig. 35 shows another example of coursed rubble in which the depth of the courses varies, but the stones in each course are of uniform height.

48. Walls With Brick Quoins.—Fig. 36 shows a rubble wall with **brick quoins,** or corners, at *a*. Red brick is usually selected, and the quoins are formed with from four to eight courses of

bricks, the dressings, band courses, and openings with arches, being formed with bricks in a similar manner. In this case, all

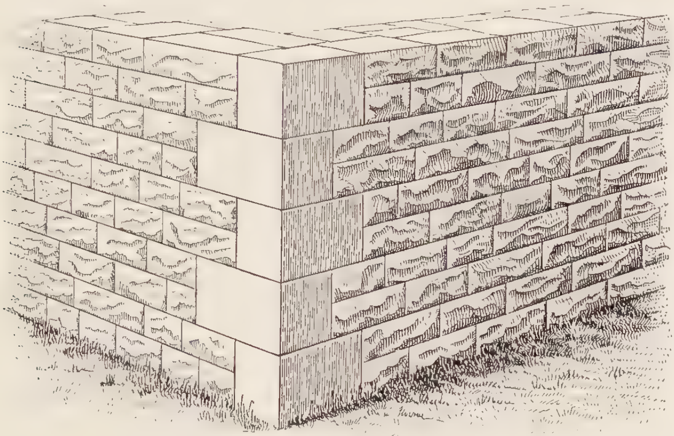


Fig. 34

the top and bottom joints of the rubble work have *level beds*, as at *b*. This makes a very effective wall, and can be built cheaply when the stone used splits readily, or can be laid on its natural

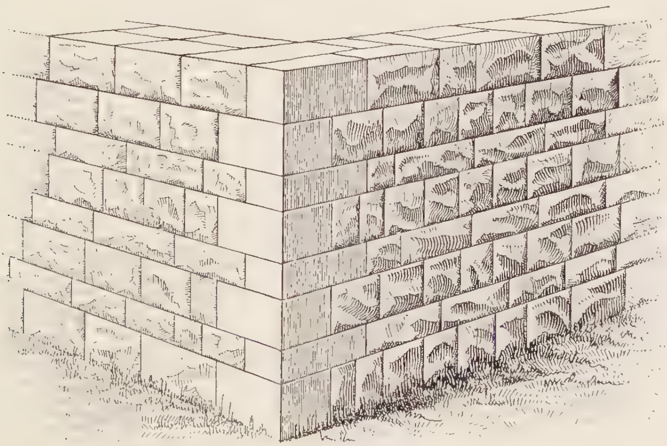


Fig. 35

bed, thus requiring but little dressing, or when good stone for dressings is difficult to get.

49. Flint Work.—Fig. 37 shows a variety of rubble work

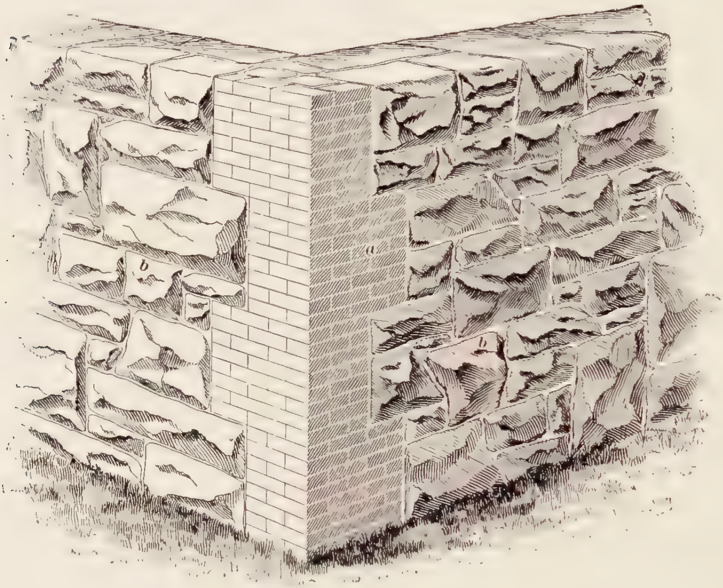


FIG. 36

that is much employed in districts where flints abound. The

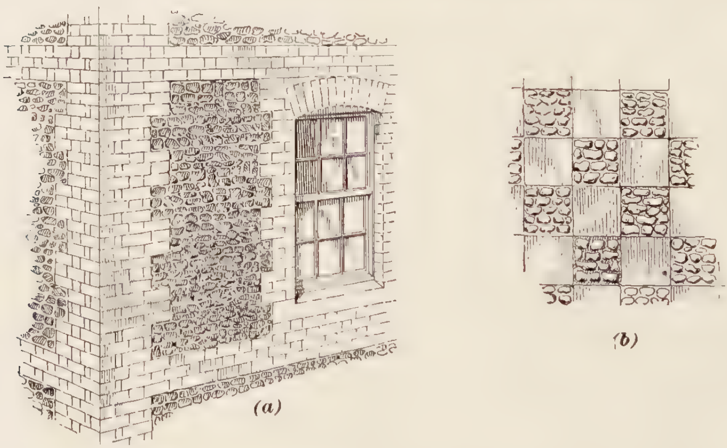


FIG. 37

walls may be built throughout of flints, in which case they are

often faced with small uncut stones, or the flints may be used merely as a facing. The larger stones used for facing are usually *knapped* or *polled*, that is, split so as to show a vertical face, but for the best work they are roughly squared and laid in regular courses, as shown in Fig. 38. The facing flints, which are small and of irregular form, are first laid, preferably in cement mortar, to a height of from 6 to 9 inches. The filling or hearting is then filled in and thoroughly flushed up or grouted with mortar. It is necessary that great care be taken to have the stones well bonded together.

The quoins, window, and door dressings, as shown in Fig. 37 (*a*), are always built in stone or brick, and lacing courses of masonry or brickwork are introduced at intervals of about 6 feet, to give strength and obtain regularity. A very fine effect is obtained by building flint walls as coursed header work, arranged so that the headers are perfectly square, equal in width to the spaces between them, and laid in alternate courses, as shown in Fig. 37 (*b*). Another effective wall decoration is produced by using flints as panels let in flush into stonework, as in Fig. 38. Brickwork may be used in a similar manner to stone, red brick being usually selected, and the quoins formed with from two to four courses. The dark colour and smooth texture of the flints, in combination with the stone or brick dressings, make a very beautiful wall surface, and much effective work of this kind is seen in the eastern counties of England. Fig. 39 shows part of a church having a porch executed in flint work, with stone quoins and dressings; in this case the flints are split and their surfaces left rough and uneven, giving a pleasing effect. A detail view of the flint work found in this porch is shown in Fig. 40.

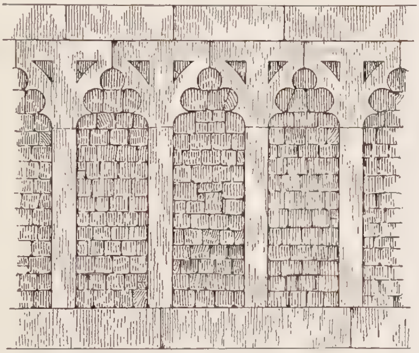


Fig. 38

BLOCK IN COURSE

50. The **block-in-course** method of building, shown in Fig. 41, does not differ materially from coursed rubble, for in this case

FIG. 39

the courses are formed with stones of equal height for each course, but differing in length, the courses varying from 6 to 12 inches in height. The walls are of a larger and better quality of stone,

usually squared with fairly fine ends, and the average of the courses is deeper and the joints finer than in coursed rubble work.

FIG. 40

Through bond stones are shown at *a, a,* Fig. 41. This work is

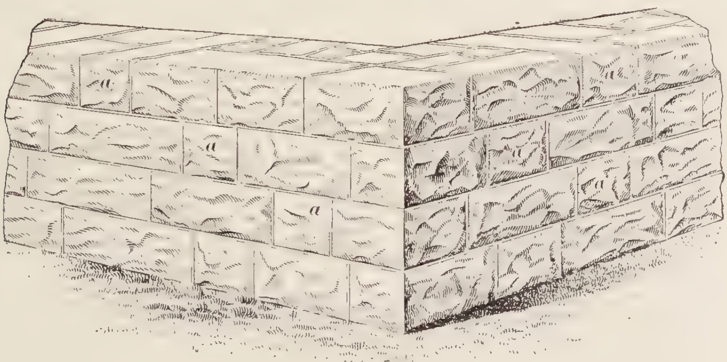


FIG. 41

much used by engineers for the facing of large piers in stone districts.

ASHLAR

51. Definition.—**Ashlar** is the term given to the facings, or veneer of stone, of a brick or rubble wall in which the joints of the blocks are worked as smooth and as true as possible. It is the best class of masonry, the blocks being usually over 12 inches in

depth and carefully squared and prepared with fine beds and vertical joints not more than $\frac{1}{8}$ inch thick. In the finest class of ashlar, the courses are of uniform height and worked in regular and uniform lengths, so arranged that the alternate courses bond.

52. Best Stone for Ashlar.—Granite and the most compact sandstones and limestones should be used for ashlar masonry, for, in pitching, the spalls fly off more easily and leave the fracture in sharp lines, whereas with the softer kinds of rock the fracture has a bruised and crushed appearance.

53. Setting Out Ashlar.—If ashlar in regular courses and sizes is to be used, drawings should be made showing each different-sized stone, the heights of the courses, and other necessary details. The drawings for public and office buildings usually show every stone, unless ordinary ashlar is used, in which case it is only necessary to show the quoins and jambs on the drawings, together with enough of the ashlar to indicate the character of the work desired.

54. Cutting Ashlar.—In cutting ashlar, no stone should have a bed less than 7 inches wide, and for first-class work the width of bed should equal the height. Larger stones should also be worked in as headers or bond stones, and should be cut accordingly. All the beds should be cut true to the square, or the width of bed will be of little value; the backs also should be roughly cut, in order that the work may be solidly built. The vertical joints may be cut a *little slack* to the square on the back, thus forming a dovetail of the mortar; but the greatest care should be taken to cut the level beds true, so as to prevent rain-water from soaking into the wall. The backing should be carefully brought to the same levels as the facework courses, and no headers should be shorter than 16 inches on bed nor placed more than 10 feet apart in each course.

55. Dressing Ashlar.—In dressing ashlar, the first finish to be considered is the plain rock face, which, although the simplest, is not the least effective. The block must first be cut true and square all round, forming beds and vertical joints, after which straight lines are drawn round the edges, about 2 inches

from the face of the block, and made perfectly true out of wind with one another. Then a wide pitching tool is used to cut along these lines, knocking off the surplus material and leaving the face free from tool marks. If, however, the block is very large on the face, it is sometimes necessary to regulate this face by using a pointed tool, working from the centre outwards, and obliterating the tool marks as the work proceeds. When finished, the face should have a somewhat regular broken appearance, with about 2-inch projections from the setting arris. Sometimes, window and door openings are left rock-faced in the reveal, but such practice leaves the lines of these openings too undefined and unshapely. It is considered that the best method is to cut the reveals clean in all openings, with either a tooled or rubbed finish. The regular band courses should also be clean cut, as by so doing the surface is broken up much better and the rock-faced work is shown off by contrast.

56. Fig. 42 shows an ashlar wall where the pieces are uniform in size ; when such stones can be obtained readily, this is not

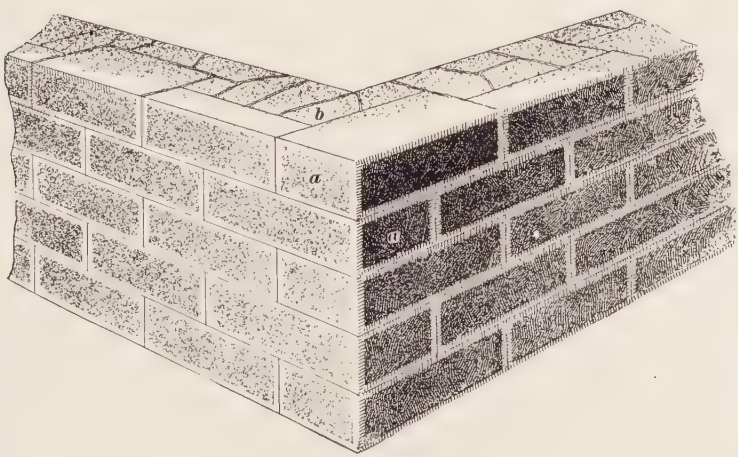


Fig. 42

a very expensive method. The ashlar *a* and the backing *b* consist of ordinary rubble. A good effect is produced by making the courses so as to be of two heights, but cut in regular

sizes, and having the vertical joints in alternate courses directly

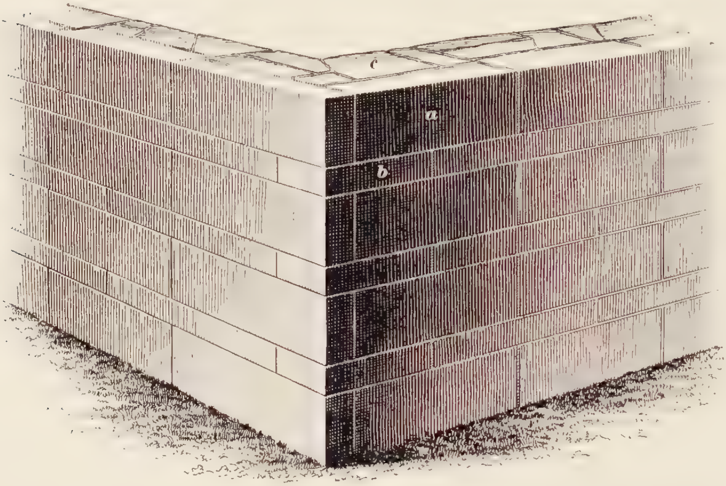


Fig. 43

over one another. This class of work is shown in Fig. 43, in

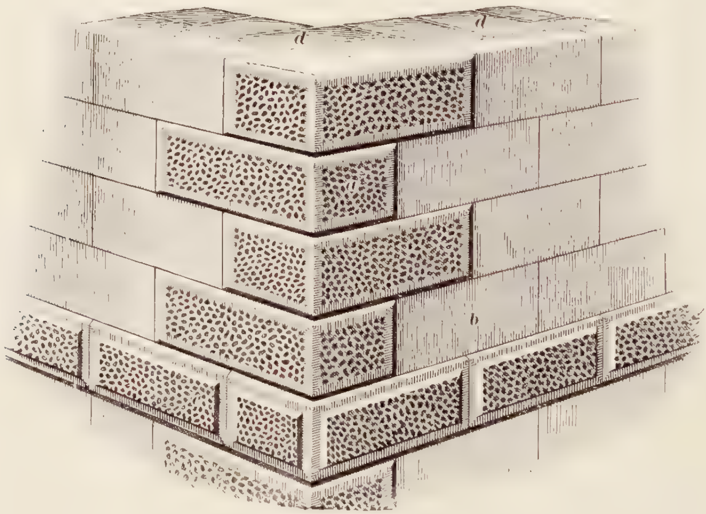


Fig. 44

which *a* is a 14-inch course; *b*, a 6-inch course; and *c*, the

backing. The latter may also be brick, as the ashlar can be well bonded into it. If the narrow band course *b* is rock-faced, or has some different finish than the wide courses *a*, the appearance of the work will be further improved.

57. The stonework of many public and office buildings has rustic quoins and base or band courses, as shown in Fig. 44. Here, *a* indicates the quoins, having a 1-inch bevel, or chamfer, at the joints; *b*, the plain, rubbed, or tooled stones forming the face of the wall; *c*, the rustic band course, having a $1\frac{1}{2}$-inch chamfer cut on it, so as to project beyond the quoins; and *d*, *d*, the stone or brick backing.

58. Among other forms of working plain rustic ashlar may be mentioned the shallow rebate round the edge of each stone, the joint being at the top of the rebate and not at the bottom, as worked this way water is less likely to penetrate at the joint. Another method is the **V** joint, a chamfer being worked all round the edge of each stone and at the vertical joints. When rusticated or vermiculated surfaces are given to the stones, increased prominence is given to them by the use of a group of small mouldings running round the panels. These are not confined to the rectangular blocks of plain walling, but may be used to emphasize the large blocks or voussoirs forming an arch, and in large structures often fulfil an important part in the design. These methods, however, are very expensive, owing to the great amount of dressing required.

59. Setting Ashlar.—Ashlar is laid in regular courses with continuous horizontal joints, as in Figs. 42, 43, and 44, or worked with headers *a* and stretchers alternately, Fig. 45, much the same as Flemish bond in brickwork. Ashlar is not always as regular as this, for both the courses and the separate stones may vary in size, but all have straight and horizontal beds, and the vertical joints are kept plumb; failure to do this mars the effect very materially. In forming ashlar walls, it is not unusual, when a plain face is adopted for the general surface, to use vermiculated or rustic quoins and band courses, as in Fig. 44, and, with certain styles of architecture, to mark the outline of

every stone by a sinking, thus giving more variety and character to the building.

In laying the stones, the dry stone should be fitted for the position, and then the bed should be prepared and the stone put into its place. It should then be tested with the spirit level,

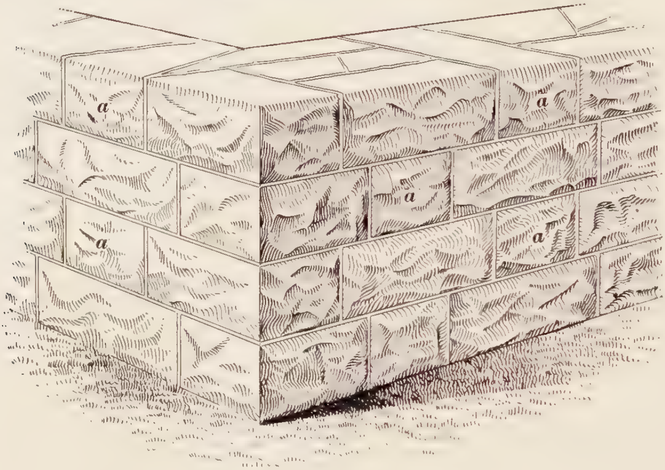


FIG. 45

and if not perfectly true should be slightly shifted with the help of a wooden mallet. If this is insufficient, it must be raised and the mortar bed adjusted where necessary, so that the stone may be set level. Great care is required to see that the mortar is spread truly and evenly, otherwise there is danger of fracture due to uneven settlement.

60. Backing Ashlar.—The expense of ashlar masonry is such that it is commonly used merely as a facing, being backed with either rubble masonry or brickwork. It is only on works of great importance and solidity that it is used throughout the whole thickness of the wall. The minimum thickness of the ashlar face should never be less than 7 inches, and it should be so arranged that about one-fourth of the total area of the face is built into the backing for at least an additional 5 inches. Stone facework is usually bedded in lime mortar, as cement stains the face of the stone.

Both stone and brick are used for backing, but in most cases brick is the cheaper, and hence is more extensively used. When using bricks, the joints should be made as thin as possible and cement mortar employed, so as to avoid shrinkage ; this backing should never be less than 8 inches thick.

61. When a hard laminated stone with flat parallel beds can be obtained, it should be used, as it is considered to be a stronger backing than brickwork. Irregular rubble walls should not be used for dwellings higher than two or three stories, unless the walls are made at least one-fourth thicker than when brickwork backing is used. All backing, whether of brick or stone, should be carried up at the same time and built in courses of the

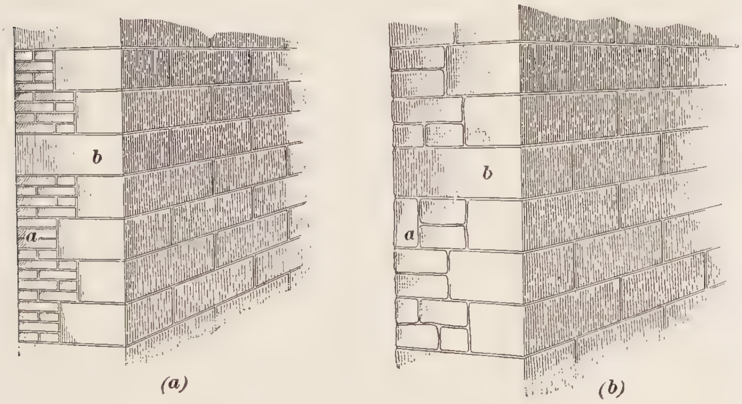


FIG. 46

same thickness as the ashlar. This is illustrated at *a* in Fig. 46 (*a*) and (*b*).

If the courses are not over 12 inches high, they are usually bonded sufficiently to the backing by making every other course thicker, and by having one through bond stone to every 10 square feet of wall, as shown at *b* in Fig. 46 (*a*) and (*b*). This method is called a *toothed bonding*.

62. Ashlar Bonding.—In Fig. 47 is shown an example of a building where the main part is constructed of ashlar and the

Fig. 47

two towers at the corners are built of squared and snecked rubble. These two styles of masonry form an internal bond, which might be called an *inverted corner*. It will be noticed that the courses in the squared and snecked rubble are so arranged that they come level with the joints in the ashlar, thus permitting the two parts of the building to be toothed, or bonded, together.

63. Fastening Thin Ashlar.—Although not so strong as a toothed bond, an ashlar facing of from 2 to 4 inches in thickness is often used, especially when marble or other expensive stones are employed in the construction. In such cases, each piece of ashlar should be tied to the backing by at least one iron clamp, or anchor, similar to that shown in Fig. 48, while if the stones are more than 3 feet long, two anchors are generally used. All iron clamps, or anchors, should be either galvanized or dipped in hot tar or asphalt, to prevent the formation of rust on them.

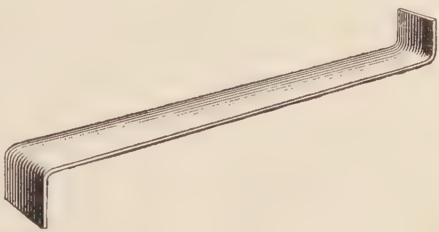


Fig. 48

Belt courses extending 8 inches or more into the wall should also be laid about every 6 feet in height to give support to the ashlar. When a wall is faced with thin ashlar, the effective bearing strength is only that given by the thickness of the brick or stone backing, the facing not being relied on for that purpose.

MASONRY

(PART 2)

ARCHES AND ARCH CONSTRUCTION

INTRODUCTION

1. Origin.—An **arch** is a mechanical arrangement of blocks of any hard material disposed in the line of some curve and supporting one another by their mutual pressure. The origin of the arch is lost in antiquity, but it was not used as an architectural feature until the rise of the Roman Empire. The mediæval architects used it very extensively, but to-day steel beams are taking its place, since they are not so expensive to put into place. In Fig. 1 is shown a French example of the use of arches; it is taken from the Château de Coucy, which was probably built in the year 1225. Here arches are used to span all openings and support all floors. In the lower story, the niches are divided into halves *a*, *a* by arches, the lower part being used for storage, while the upper part, extending into long narrow openings in the outer wall, is intended for light and defence in time of war. The wall at the base is almost 18 feet thick; in the third story it is made thinner, and thus forms a balcony *b*, which enabled a large number of people to assemble on that floor. The example shown in Fig. 2 is of a mediæval house. The passages that give access to the various rooms are galleries on the outside of the building. These galleries, however, are of such a height as to admit air and light above them, and are supported by piers, or buttresses, which have arches

sprung between them, as shown. The floor, however, is not supported by arches, as in Fig. 1, but by wooden beams. The roof is also of wood, and is built on a steep pitch, as was the custom in those days.

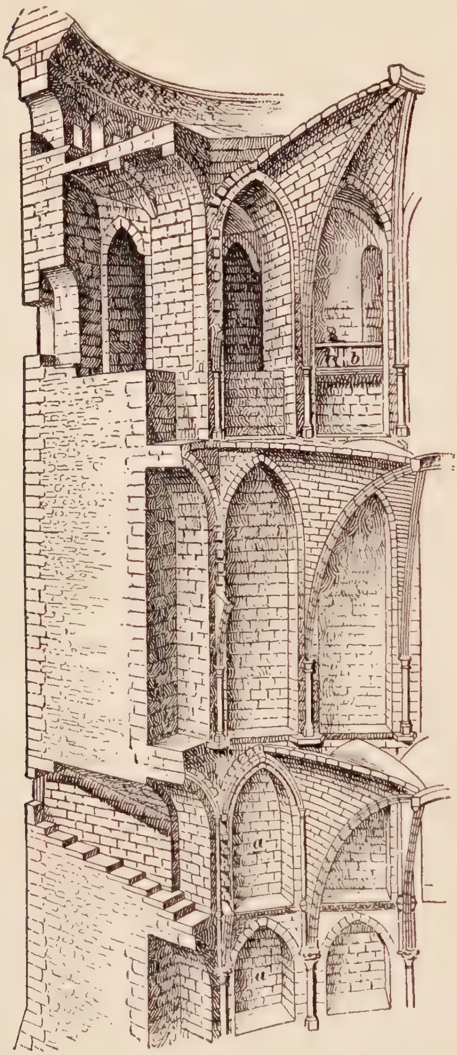


Fig. 1

2. Utility of Arches. Stone arches are used in both stone and brick structures, but in some ways a stone arch is not so satisfactory as a brick one. Being composed of a few large pieces instead of many small ones, as is a brick arch, the bond is not so perfect; and, consequently, the stone arch is somewhat more liable to settle and crack. The amount of masonry in heavy piers, etc., can, without injuring the stability of the structure, often be considerably diminished by the use of arches, provided the stone and the footings are capable of carrying the increased load. If necessary, the pressure on the soil may be distributed by using inverted arches.

3. Names of Stones Used in Arches.—In Fig. 3 is shown a stone arch. In it the various *arch stones* or *voussoirs* b, c, and d, are of about the same size on the face, but the thickness (back into the wall) should vary as much as may be necessary for proper bonding; the face also sometimes varies. The lowest voussoirs, or skew backs, b, b are sometimes termed *springers*, and the uppermost or central stone d the *keystone*. Other terms used

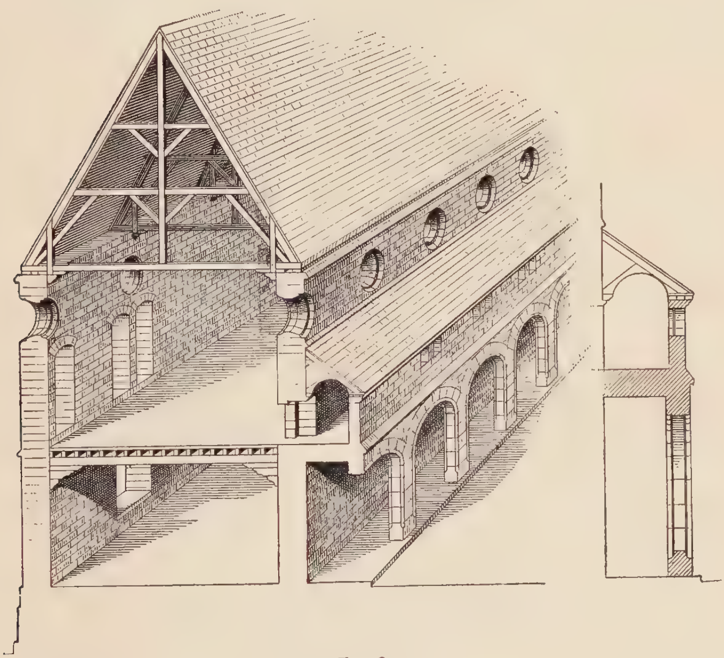


Fig. 2

in arch construction, such as *springing line*, *rise*, *intrados*, etc., are shown in Fig. 3. The *abutments* a, a are the piers from which the arch springs.

4. Stability of Arches.—In building construction it is not customary to determine the proportions of arches of small span by calculation, the appearance being usually the controlling factor. But when the arches are of considerable span, the position of the *line of resistance* should be determined; as

that determination is beyond the scope of this Paper, merely the conditions necessary for stability will be mentioned. The well-known authority Rankine, says: "The best course in practice is to assume a height for the keystone based on the dimensions of good existing examples." This statement holds good in connection with the construction of the arches that an architect ordinarily has to design.

Having fixed the height of the keystone, the voussoirs are all made the same height in arches of small span, while with longer spans the voussoirs often vary in height, increasing gradually

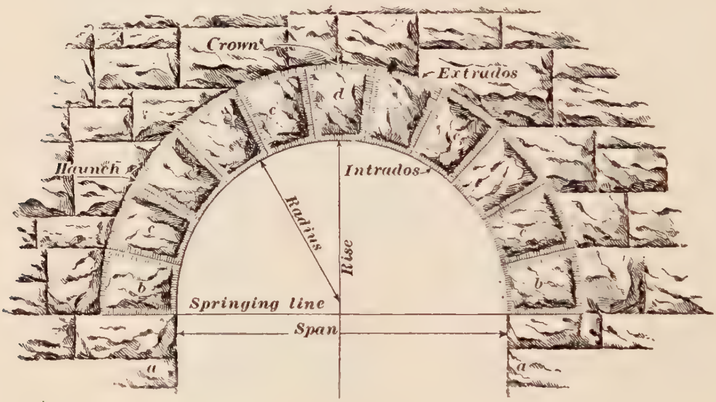


FIG. 3

from the crown to the skew backs, so as to preserve a uniform pressure on the stones as the load becomes greater.

5. To ensure the stability of an arch, two conditions besides the one just mentioned must be satisfied: The pressure shall not cause the opening of the joints, and the direction of the pressure shall not cause one voussoir to slide on another. These requirements are met by making the *arch ring*, or the single row of voussoirs, of proper depth. For small arches they generally do not need to be determined theoretically, and are left to the structural engineer. When flat arches, those having but little rise, give way, they do so by breaking in the four parts, opening at the crown of the intrados and at some joint

on the extrados, the two upper parts falling inwards and pressing the lower parts outwards. In pointed arches, the reverse is the case, the lower portions tending to fall into the opening and to force the upper parts outwards.

KINDS OF ARCHES

6. Derivation of Names.—Arches are frequently named from the curve of the intrados, as *semicircular, segmental, semi-elliptic, pointed,* etc. They are also sometimes named from the period in history in which they were most used, as the *Tudor arch;* or from a nation that devised them, as the *Moorish arch.*

7. Early Arches.—The arch shown in Fig. 4 is probably the form of the first arch ever built, and is therefore the starting point of all arch construction. It possesses several disadvantages, however. Being composed of only two stones, these stones are subjected to transverse stress as well as to direct compression. Therefore, this arch may fail by bending instead of by direct compression, as bending will cause tension on the under side of the stone, and most stones are weaker in tension than in compression. For this reason the arch is not applicable to long spans.

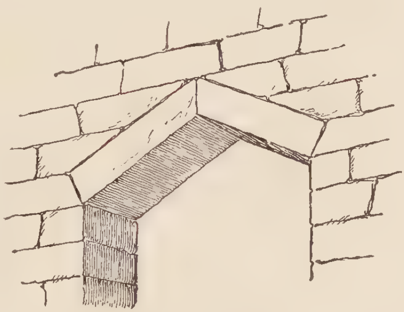


Fig. 4

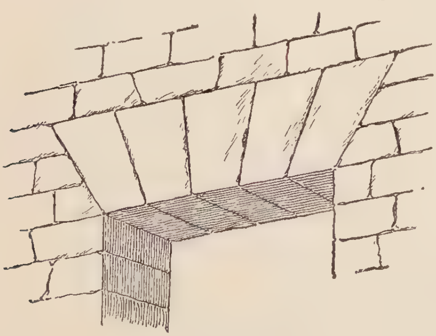


Fig. 5

8. Flat Arches.—The arch shown in Fig. 5 is known as a **flat arch**, and while not chronologically next in order to that just shown, it follows in

simplicity of design. This arch is used extensively over windows and other short spans where a flat soffit is desired, and very often in brick buildings. All the voussoirs are wedge-shaped, so that it would be difficult to force one down out of its place. This arch is usually built with a rise of $\frac{1}{8}$ inch per foot of span, which allows for any settlement that might occur

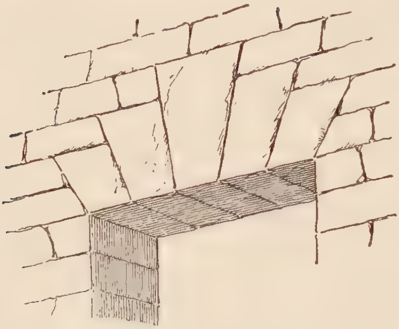


FIG. 6

while the mortar is setting. In Fig. 6 is shown a more ornate flat arch than the one shown in Fig. 5, but different from it only in that the voussoirs are of different sizes. Many other styles are used, but they are all built on the same principle as those described.

9. Segmental Arches.—If the rise of a flat arch is increased, the arch will look like the one shown in Fig. 7, which is called a **segmental arch**. The curve of the intrados is struck from a centre *o*, which in an arch of this character is always below the springing line, while the radius of curvature of the intrados is always greater than one-half the span. The arc of the extrados is usually struck from the same centre as the intrados, but any other form of design may be carried out.

FIG. 7

10. Semicircular Arches.—When the centre of curvature of an arch is on the springing line, and when the radius of curvature is equal to one-half the span, the arch becomes a common **semicircular arch**, as is illustrated in Figs. 3 and 8. In Fig. 3,

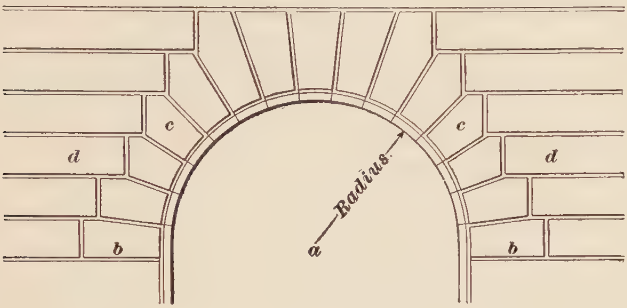


FIG. 8

the arch ring is of equal depth all round and the voussoirs are all of the same size; the dressing is rock-faced with pitched joints. Sometimes the voussoirs have a margin draught, as shown at *b* and *c*. Arches that are used in coursed ashlar are

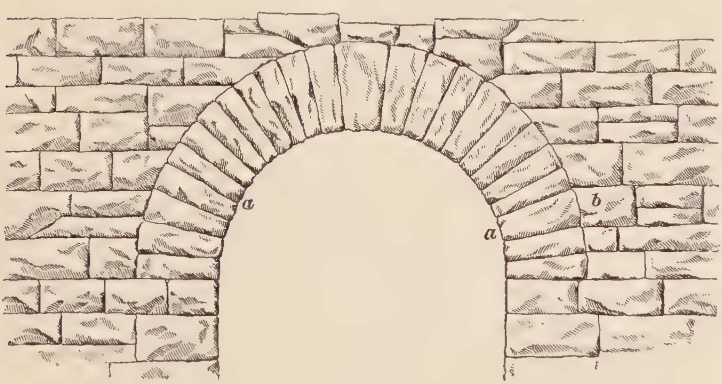


FIG. 9

often built with the upper surfaces of the voussoirs tabled, so that the arch ring may bond in with the coursing of the plain walls, thus adding stability to the work. In Fig. 8, *a* is the centre of curvature of the arch; from *b* to *b* is the springing line; *c*, *c* are the arch stones; and *d*, *d* the coursed stonework. Arches

of this description are more expensive to construct than those in which the intrados and extrados are concentric, on account of the greater number of moulds required, the increased quantity of rough stone needed, and the work necessary to properly dress the voussoirs.

11. Rubble Arches.—For rough work, arches are sometimes built of **rubble,** as shown in Fig. 9, in which *b* represents the wall carried by the rubble arch, the arch stones *a* of which should be narrow and roughly dressed to a wedge shape. Such arches should always be laid in cement mortar, as they depend considerably on the adhesive power of the mortar for their stability.

12. Moorish Arches.—If the centre of curvature is raised above the springing line, as shown in Fig. 10, the arch is called

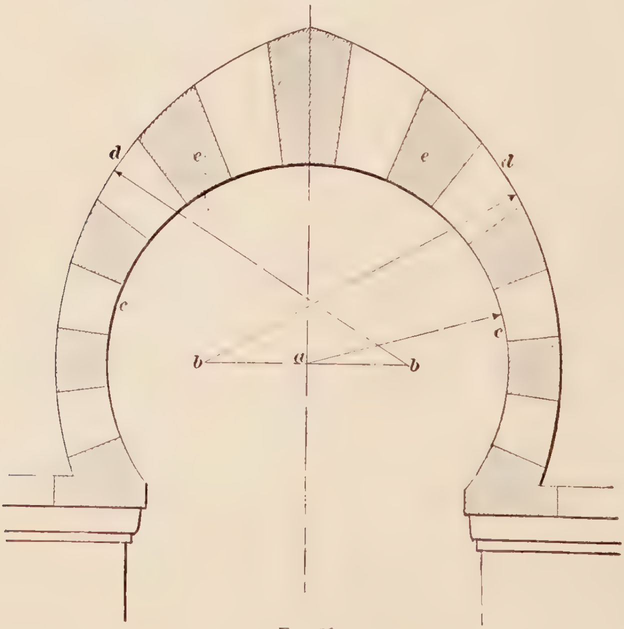


FIG. 10

a **horseshoe, or Moorish, arch.** The Alhambra, at Granada, in Spain, has some of the best examples of this arch. Sometimes,

the Moorish arch is built with the intrados and extrados concentric, and often with the intrados having a horseshoe form and the extrados a pointed form; the example given shows the latter method of construction. At *a* is shown the centre for the horseshoe intrados; at *b*, *b* are the centres for the pointed extrados of the arch; *c*, *c* indicate the soffit of the horseshoe arch; *d*, *d*, the extrados; and *e*, *e*, the voussoirs.

13. Stilted Arches.—If the portion of an arch below the centre of curvature is made vertical, as shown in Fig. 11, instead of curving in again, as in the Moorish arch, the arch is said to be **stilted.** This style is often used where two or more are to be placed adjacent to one another. The *stilts*, that portion between the springing line and the abutments, are unable to take any horizontal thrust, and the arch must therefore be properly supported on the sides at a level with its centre of curvature. Many forms of arches may be made stilted, as, for instance, the *lancet arch*, which will be described later.

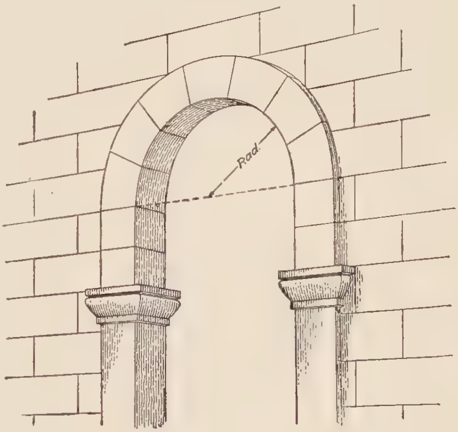


Fig. 11

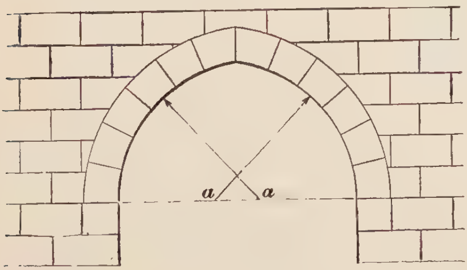


Fig. 12

14. Depressed, or Drop, Arches.—Instead of turning the entire intrados from one centre, two centres may be used. This forms an arch known as the **depressed,** or **drop, arch,** an illustration of which is given in Fig. 12. The sides

are formed by circular arcs drawn from the centres a, a with the same radius. This method makes a point in the crown of the arch, for which reason it is sometimes called a *pointed arch.*

15. Venetian-Gothic Arches.—Fig. 13 shows an arch having the intrados semicircular and the extrados pointed; such arches are found in Venice, and are sometimes termed **Venetian-Gothic arches.** At a is the centre for the semicircular intrados; at b, b are the centres for the extrados, or pointed arch, and c c is the springing line. The more closely the points b, b approach each other, the less pointed is the arch, and when these two points become one, as at the point a, the arch is a common semicircular arch. Conversely, as the two centres of curvature separate, the arch becomes more and more pointed.

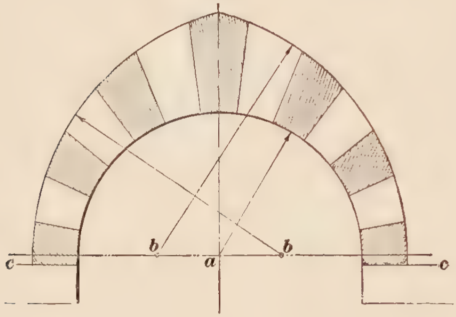


Fig. 13

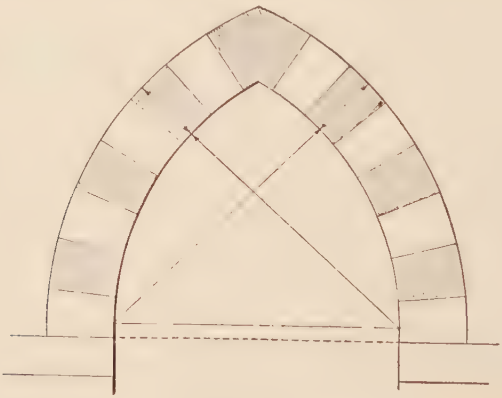


Fig. 14

16. Equilateral Arches.—Fig. 14 represents a pointed arch known as an **equilateral arch.** In an arch of this character, the

centre of curvature of one intrados is on the curve of the other intrados, and the extrados are concentric with their respective intrados.

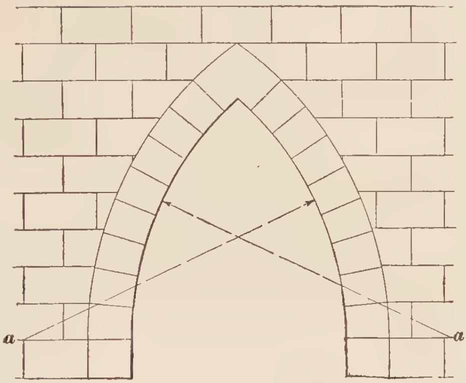


Fig. 15

17. Lancet Arches. The centres of curvature of a depressed arch may be placed at a still greater distance apart than in the equilateral arch shown in Fig. 14. In Fig. 15 is shown an arch in which these centres *a*, *a* are placed some distance beyond the

Fig. 16

extrados, thus causing the apex of the arch to be acutely pointed.

This arch is also known as a **lancet arch.** These depressed arches, and the *Tudor arch*, which is described later, are much used in Gothic architecture.

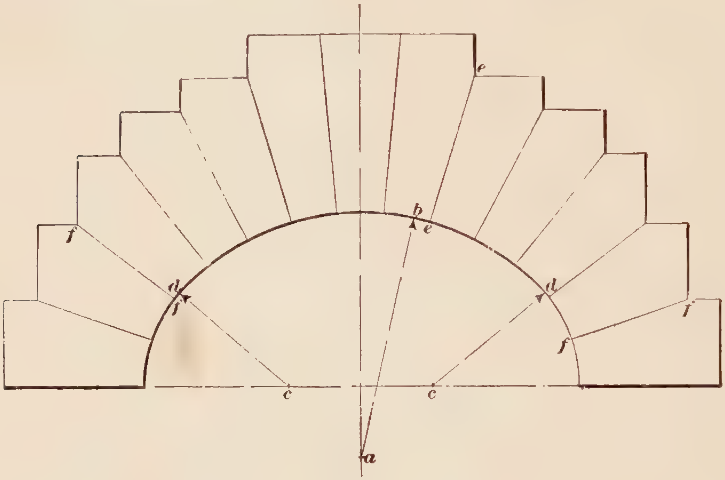


FIG. 17

18. Two-Cusped Arches.—The **two-cusped arch,** shown in Fig. 16, is really a variety of depressed arch. The extrados are made like the extrados of a lancet arch, but the intrados

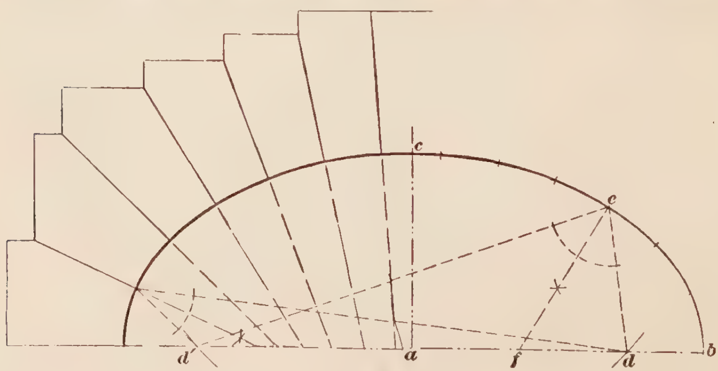


FIG. 18

are the combination of a circular arch and a depressed arch. There are so many styles of this arch that it is impossible to lay down rules giving any definite proportions between the parts.

19. Three-Centred Arches.—Arches having an elliptic, or oval, form are often used in architectural work. These may be formed either of true elliptic curves, or approximately of three or more centred circular arcs. Very flat elliptic arches are not suitable for any considerable span, and, if built, should have large piers or abutments, or beams may be placed above

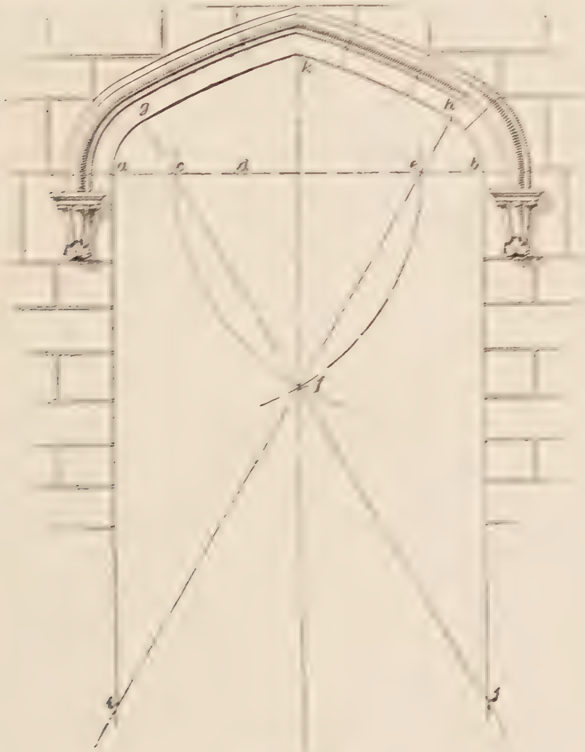


FIG. 17

the arch to relieve it of some of the load. The method of finding the direction of the joints in a three-centred, or false, elliptic arch is shown in Fig. 17. The radius $f\,k$ for the middle of the arch may be any length greater than the rise of the arch; the radii $c\,a$ for the two haunches may be any length less than the rise. The joints of the voussoirs in the central portion are

drawn with a as a centre, as at $e\,e$, etc.; and the joints for the haunches are drawn with c, c as centres, as at $f\,f$, etc. The distance between joints is merely a matter to be decided by the taste of the architect. A method of finding the voussoir joints in a **true elliptical arch** is shown in Fig. 18. Find the foci of the ellipse by striking arcs from c, the point where the minor axis strikes the curve of the ellipse, with $a\,b$, or one-half the major axis, as a radius, cutting the major axis at d and d'.

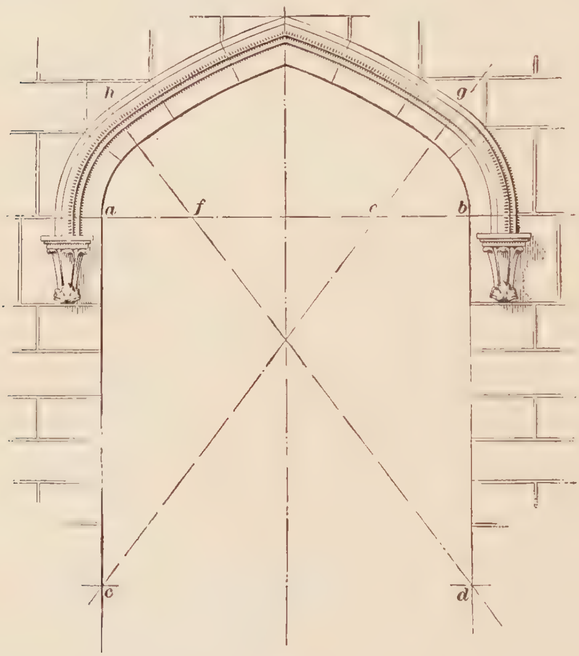


Fig. 20

Let e be the point where the direction of the joint is to be found. Draw $d\,e$ and $d'\,e$, and bisect the angle $d\,e\,d'$, as at $e\,f$; then $e\,f$ is the direction of the joint at e.

20. Four-Centred Arches.—Fig. 19 shows an example of a **four-centred arch**, also often called a **Tudor arch.** The span $a\,b$ is divided into six equal parts, as at c, d, etc. To find the centres for the longer radii, with c and e as centres and a

radius *c e*, describe arcs intersecting at *f*; draw *f c* and *f e*, and produce these lines to *g, h, i,* and *j*. The last two points will be the required centres for the middle part of the arch. With *c* and *e* as centres and a radius *c a*, describe arcs *a g* and *b h*; with *i* and *j* as centres and a radius *i h*, describe the arcs *h k* and *g k*. In Fig. 20 is shown an arch similar in construction to Fig. 19, but the span *a b* is divided into only four equal parts. The distances *a c* and *b d* are each made equal to *a b*; lines are then drawn from *c* through *e* and produced to *g*, and from *d* through *f* and produced to *h*. The arcs are then struck from *c* and *d* for the upper portion, and from *f* and *e* for the lower portion.

21. Ogee Arches.—Fig. 21 shows a four-centred arch with a reverse curve at the apex; it is sometimes called an **ogee arch.**

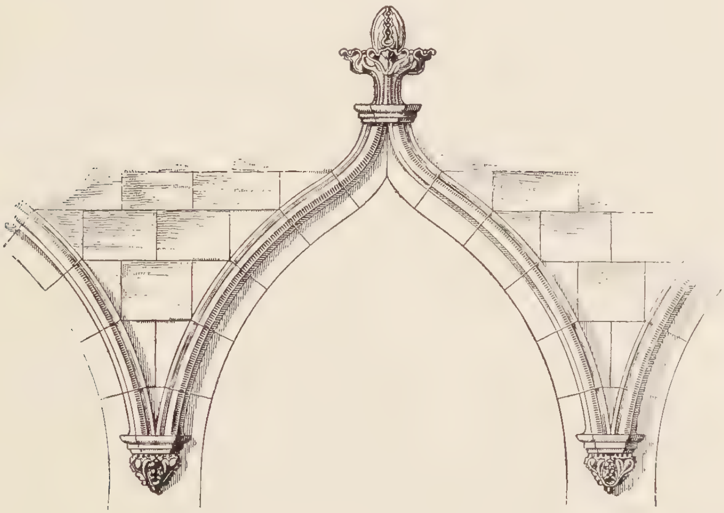


Fig. 21

This arch is usually, although not necessarily, made stilted, the stilt being about one-seventh of its total height.

22. Rampant Arches.—Fig. 22 shows a **rampant arch**; it is used in a flying buttress, as in the illustration, or to support a flight of stairs. To construct a rampant arch, draw the base

line $a\,b$ equal to the horizontal length of the span. At a, set off the desired angle of inclination $b\,a\,c$. Draw a vertical line $b\,c$,

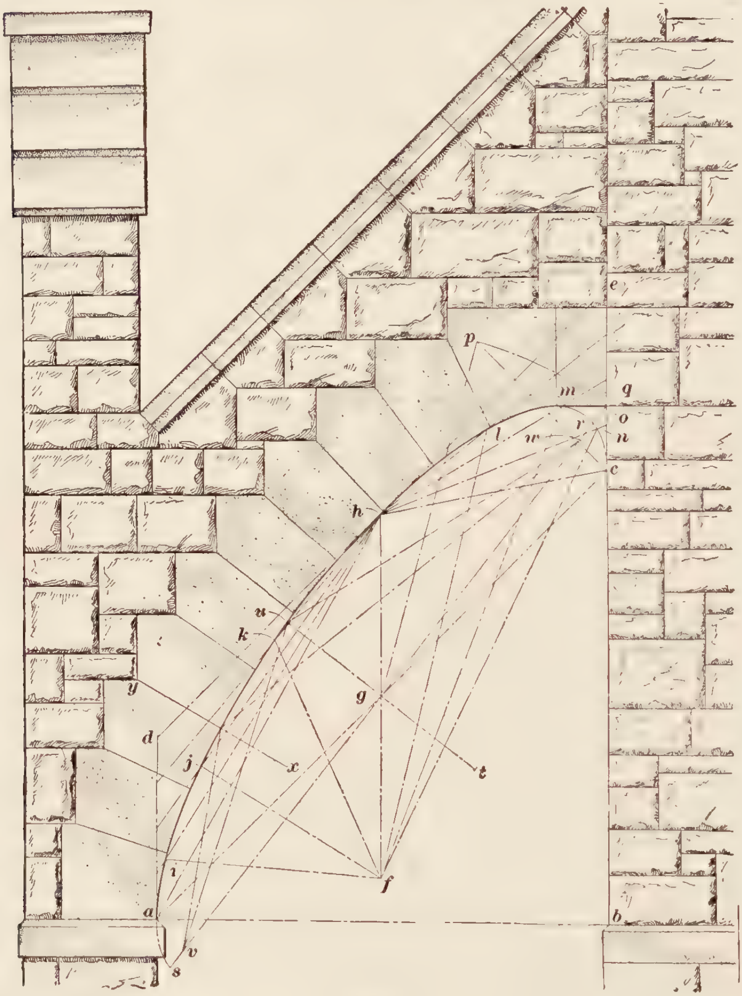


FIG. 22

intersecting the line $a\,c$ at the point c. Bisect $a\,c$ at g. At the points a, c, and g draw lines perpendicular to $a\,b$, as $a\,d$, $c\,e$, and $f\,g\,h$. The perpendicular $g\,h$ is made equal to the amount

of rise it is proposed to give to the arch, and *f g* is made equal to *g h*. Now, through *h*, draw the line *d e* parallel to *a c*. Divide the line *a c* into any even number of equal parts, and divide *a d* and *c e* each into one-half as many equal parts. From *h*, draw lines to the points on *a d* and *c e* just found. From *f*, draw lines through the points on the line *a c*, producing them to intersect those first drawn, as at *i, j, k, l, m,* and *n*. These points, together with the points *a, h,* and *c*, lie on the required curve of the intrados. Usually, the descending part of the curve at the right-hand side of the arch, namely, the part *m n c*, is omitted, as it is liable to be a source of weakness. There are two ways of finishing the soffit, if the part of the curve just mentioned is considered undesirable. The arch may be designed slightly larger, so that the actual arch will meet the wall at its highest point *m*; or, from this point *m*, a horizontal line *m o* may be drawn to the wall to complete the curve. The latter method has been followed in the illustration.

23. The curve found for the intrados is an ellipse. To locate the axes and foci of the ellipse, erect *c p* perpendicular to *a c* at *c*, and make it equal in length to *g h*. With *g* as a centre and with a radius *g p*, describe an arc, intersecting *e c* at *q*. A line drawn from *q* through *g* will give *r s* as the major axis, and *t u*, at right angles to it at *g*, making *t g* equal to *g u*, will be the minor axis. Taking the distance *g r* as the radius and with *u* as a centre, describe arcs cutting the major axis at *v* and *w*. These points will be the foci of the ellipse, and the joints between the stones may be found, as at *x y*, by the method previously described.

CONSTRUCTION OF ARCHES

24. Centres.—When an arch is being built, it is carried up from both piers, or abutments, at the same time. The stones, until the ring is completed, are supported by a framework made of planks having one side cut to exactly fit the curve of the arch. This framework, known as a **centre**, is supported on posts. Usually wedges are inserted between the centre framing and the posts supporting it, which, when the arch has been completed

and the mortar has set, are driven out gradually, so as to bring the load on the arch ring without shock. The centre should be strong enough to support the weight of the arch and a portion of the wall above, as no weight should be put on the arch until the mortar in the joints has become hard. Fig. 23 represents a form of centre suitable for arches of small span. At *a*, *a* are shown the bearers, which are cut out of 2-inch plank and to a radius about 1 inch less than that of the intrados of the arch.

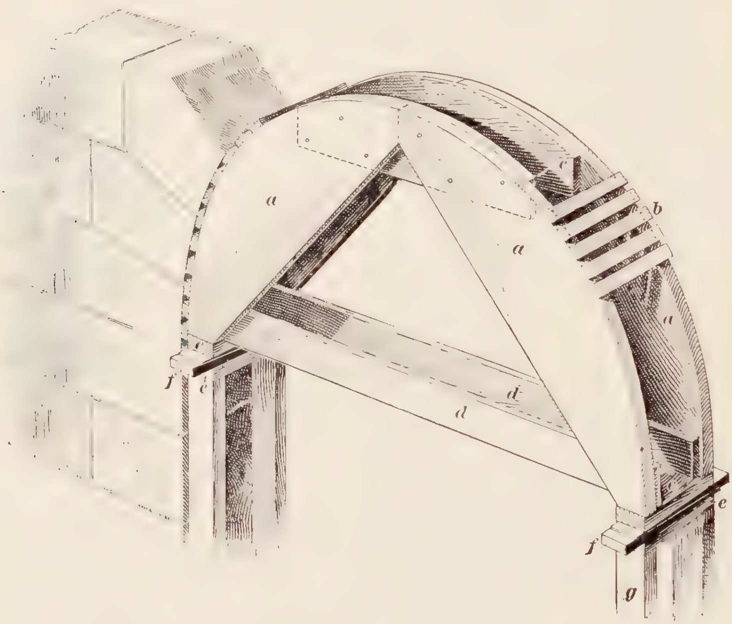


FIG. 23

At *c* are pieces of plank nailed at the crown of the centre to splice and stiffen it. Small bearing strips *b*, about 2 inches by 1 inch in section, are nailed to the curved pieces *a*. At *d*, *d* are shown the longitudinal braces; at *e*, *e*, the plates under the centre and on top of the posts; at *f*, *f*, the wedges; and at *g*, the posts, which, if quite long, should be braced at the middle with struts. For arches of considerable span, centres more strongly built are necessary. Fig. 24 shows a good form of

construction. At *a*, *a* and *b*, *b* are represented the bearers, breaking joint as shown; *c* indicates the bearing strips; *e*, the upright and *d*, *d*, the inclined braces; *f*, the tie-piece; *i*, *i*, the

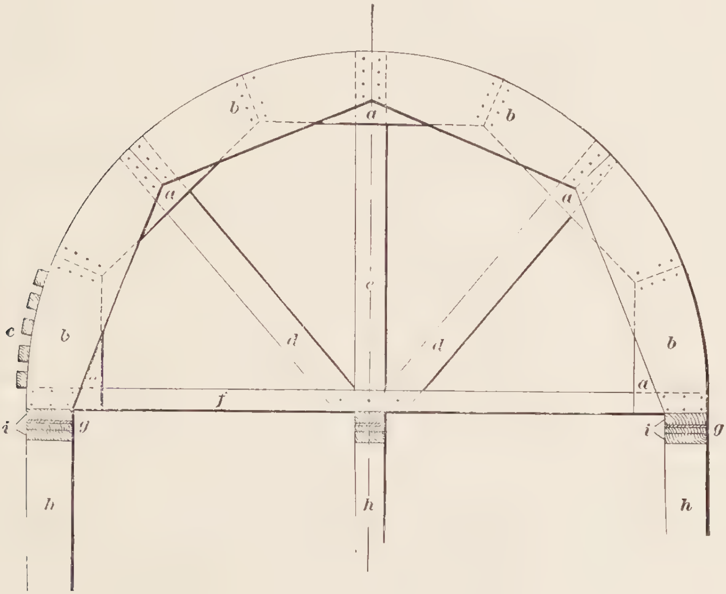


FIG. 24

bearing plates, with wedges *g*, *g* between; and *h*, *h*, the side and centre posts.

25. Voussoirs.—The ring of a stone arch should be built of the very best kind of ashlar masonry, cut so that the voussoirs bear evenly and closely against one another with the thinnest possible joints, as it is desirable to have very little mortar between the stones. The width of the arch stones is seldom less than 1 foot or more than 2 feet, and the thickness (back into the wall) varies from 1 to 3 feet. The joints of the stonework should be of the same width throughout the arch, so that the bearing may be uniform over the entire surface. The thickness of the joints depends somewhat on the character of the finish. If the work is finely dressed, $\frac{3}{16}$ inch is the usual thickness, while in rock-faced work it is seldom made less than

$\frac{3}{8}$ inch ; $\frac{1}{4}$ inch is all that is usually allowed for the best work. Narrow voussoirs, while more economical in the amount of material used, are more expensive in labour, as more cutting and fitting are required than with wider ones. Sometimes, two of the voussoirs are cut from one stone with a false joint between. This is generally done for economy, but there are times when the stability of the arch is thereby increased ; for when the skew backs are made twice the size of the remaining voussoirs, the number of joints is decreased, which tends to strengthen the arch. Usually, the arch is divided into an odd number of voussoirs, and the keystone is placed in position last.

26. Backing.—As a rule, cut-stone arches in buildings are only from 6 to 8 inches thick, having a backing of a less costly stonework or of brickwork. Large arches, especially when both sides are visible, as in some entrances, porches, etc., are often constructed as shown in Fig. 27. In this case, the stone ashlar is backed with brickwork, and tied together with clamps, as indicated at *f*.

27. Beams and Tie-Rods.—When an arch is to be built in a position where abutments of sufficient strength to resist the arch thrust cannot be provided, as, for instance, in a circular tower or near the corner of a building, one or more steel beams should be laid on the wall immediately over the arch, with the ends resting on the work forming the abutments. By this method the abutments are relieved of the arch thrust due to the load, which is, instead, transmitted vertically to the supports. A small space should be left under the central portion of the beams, so that if they deflect under the load they will not rest on the arch. The beams and stonework are tied together by securely embedded anchor rods. In building a segmental arch, it is a good precaution, if conditions permit, to tie the ends of the arch together with steel rods so as to take up the thrust until the mortar in the wall has thoroughly set.

28. Bonding.—Whenever arches are carried on piers or columns, care should be taken in cutting the springing stones so that they will bond properly into the spandrel masonry.

In Fig. 25 are shown two arches springing from a pier; if the stones *a, a* are so cut that the wedge-shaped piece *b* is necessary to fill up the space between them, there is danger that the weight of

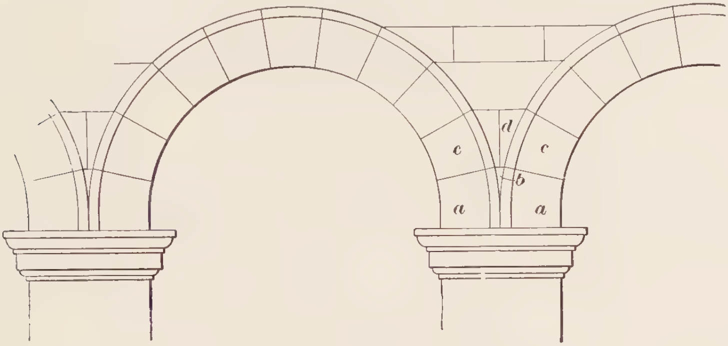


FIG. 25

masonry over *b* will force it down, and displace the springing stones *a, a*. To prevent this, the springing stone should be of one

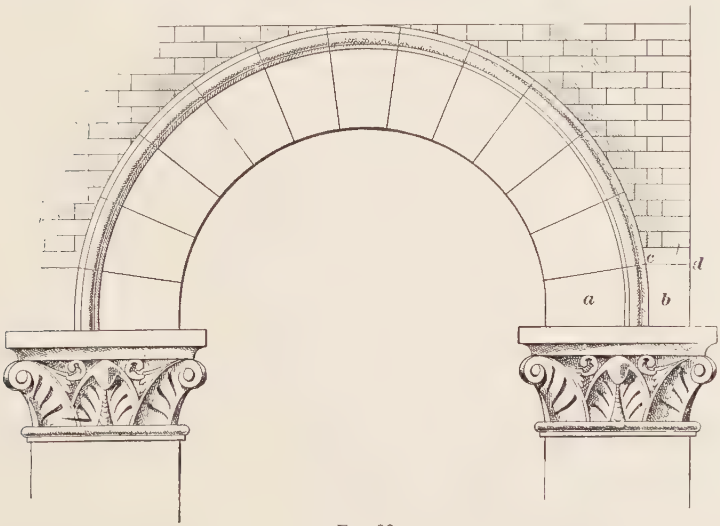


FIG. 26

piece, and those marked *c, c* should be cut so as to make a vertical joint at *d*, and thus avoid the use of the wedge-shaped piece between the two arch stones. A somewhat similar case is

represented in Fig. 26, where the back of the arch extends almost to the corner of the wall *b*. Should the brick wall rest on such a small footing, it would tend to separate from the arch, through some of the lower bricks being thrust out of place. The springing stone *a* should therefore extend clear through the wall to the face, and the brickwork should rest on the part *b*, as shown at *c d*.

29. **Mouldings.**—Although mouldings are not an essential feature of the construction, arches are often decorated with more or less elaborately dressed stone, known as **label** and **soffit**

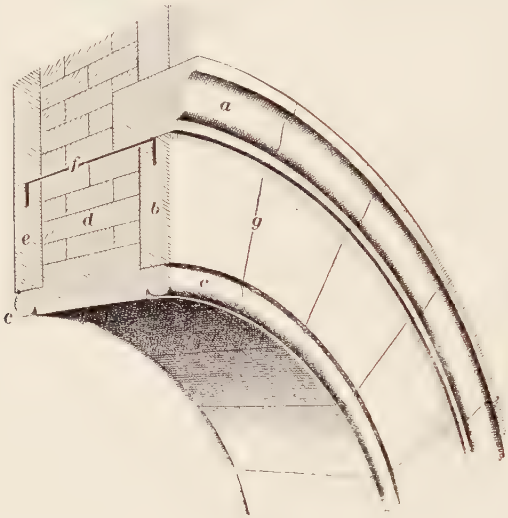


Fig. 27

mouldings. The former is sometimes cut in the voussoirs, but more often forms a separate course of thin stone bonded into and forming an essential part of the arch construction. If such is the case, the stability of the arch should not depend on the strength of the stone in the moulding. The soffit moulding is frequently in the form of a bead and cove, or three-quarter round and cove, or some similar shape. Entrance arches are often decorated with various devices cut in the soffits, especially in entrances to cathedrals, public and office buildings, etc. In Fig. 27 the label mould is shown at *a*; the arch rings, at *b* and *c*;

the soffit mould, at *c*, *c*; the brick backing, or filling, at *d*; and the voussoir joints, at *g*. Every alternate pair of voussoirs should be tied together with galvanized-iron clamps, dowelled into the stones, as shown at *f*.

APPLICATION OF ARCHES TO DESIGN

30. The application of arches to the design of buildings is shown in Figs. 28 and 29. In Fig. 28, a semicircular arch forms a setting for the doorway contained under it. The arch is not cut up with mouldings or carving, but has simply the deep cove on its front edge, giving an idea of strength and massiveness by its very plainness. This is all the more suitable, as the stone in which it is executed is of a heavy nature, being granite. The projecting keystones and voussoirs also give an appearance of strength, besides being pleasing to the eye, for they produce shadows by their projection and relieve the monotony of surface that might result from a purely flat-faced arch.

In Fig. 29 is shown an arch similar in shape to that illustrated in Fig. 28, but of much larger dimensions. Here, again, the archway forms a surrounding in which the entrance door is placed. The general effect of shadow is obtained by the deep cove on the edge of the arch, in which the doorway is set, and the projecting voussoirs of varying lengths give a pleasing outline on the flat ashlar face of the surrounding masonry. This doorway forms the entrance to Bow Church, Cheapside, London, designed by Sir Christopher Wren and erected in 1680. The beauty of its proportions is very noticeable; this, together with the simplicity of its design, have caused this doorway to be looked upon as a masterpiece of Wren's design. It is considered by many to be one of the finest doorways in the City. A second arch, of similar shape to the one enclosing the doorway, is placed between the two columns and under the entablature. It rests on either side on the stone pilasters, or *imposts*, and has a moulded keystone to give a finish under the entablature.

FIG. 28

Fig. 29

STEP AND STAIRCASE CONSTRUCTION

31. Stone Steps.—Hard stone should be used for steps at entrance doors, a single stone being used for each step, except when the openings are large. The tread, rise, and end of the steps should be dressed; the edge is often moulded. The ends of each step should be firmly supported, but the middle should be left free, for if the stones forming the steps have a bearing along their entire length, they might, after a slight settlement in the foundations, rock from side to side when stepped upon, or they might crack. In order to strengthen extra-long steps, it is sometimes necessary to insert a middle bearing; great care must then be exercised to have the middle and two end supports exactly on a line. Each step should overlap the one below at

FIG. 30

least $1\frac{1}{2}$ inches, as shown at *a*, Fig. 30 (*a*), or may be formed with rabbeted joint, as shown at *b*, and should have an outward pitch, or weathering, of about $\frac{1}{8}$ inch, to throw water off. In Fig. 30 (*a*) is shown a section through stone steps square on edge, and in (*b*) a section through similar steps moulded on edge.

32. Hanging Steps.—When stone steps are built into a wall at one end they are called **hanging steps.** The soffit, or under side, of such steps may be finished as shown in Fig. 31 (*a*), (*b*), or (*c*). In view (*a*) the steps are left square; in (*b*), the soffit is cut away to form a flush sloping face; in (*c*), the soffit of each step is moulded. In the cases shown in (*b*) and (*c*) the ends

should be left square, as shown dotted at *d*, and bedded into the wall at least 6 inches, and 9 inches where possible. Where a square bed is obtained, the step will not tend to slide, as it would were the end of the same shape as the soffit. Hanging steps should be put in place as the wall is being built ; but when this is not possible, spaces 9 inches deep may be left in the wall and

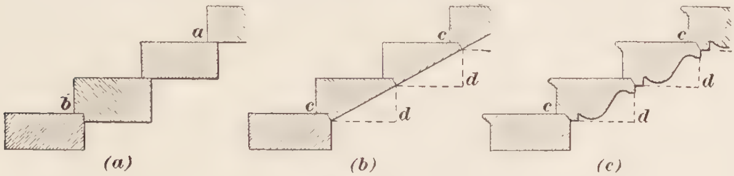


FIG. 31

the steps put in place afterwards. The joints between the steps may be made flush, as at *a*, Fig. 31 (*a*) ; rabbeted, as at *b*, Fig. 31 (*a*) ; or birdsmouthed, as at *c*, Fig. 31 (*b*) and (*c*).

The construction of hanging stone steps is shown in Fig. 32. At *a*, the landing is rabbeted into the tread of the top step, while *b* shows the manner in which each step is cut and supported

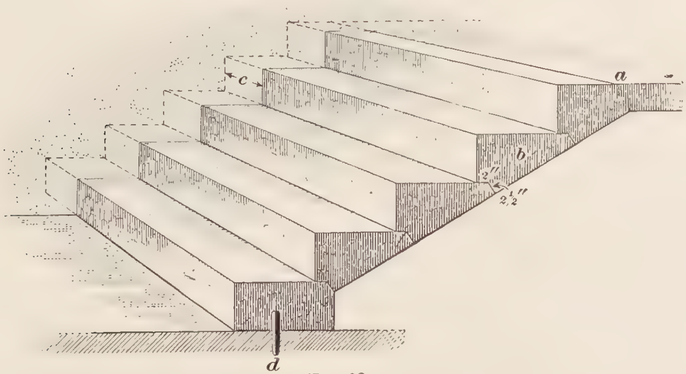


FIG. 32

by the lower one. To be safe, the bearing dimensions or amount the step is bedded in the wall, as shown at *c*, should not be less than 6 inches, as before stated. The bottom step should be firmly held in place by dowels set into the floor, as shown at *d*, as this step must sustain a certain amount of the thrust of the

whole flight. Steps having a nosing, as in Fig. 31 (*c*), have a good appearance, but are much more expensive than the ordinary square ones.

33. Stone Stairs.—In stone stairs the steps may be of solid stone or built of slabs, but the method shown in Fig. 33 is not generally used, except for outside work, when it makes a cheap

Fig. 33

and serviceable stair. The treads are usually of hard tooled or rubbed York or Arbroath stone, $2\frac{1}{2}$ to 3 inches thick, with risers about 2 inches thick. They must be built into a wall at both ends for support and fixing, and should be laid with a slight fall toward the nosing to carry off water. In flights of small width, slab treads may be used without risers.

34. Circular Staircases.—Staircases are frequently built circular on plan, all the steps being winders, or wheel steps, worked either rectangular or spandrel shaped in section. The latter form is more generally used, as then a continuous sloping soffit is formed. The stairs may be formed with steps supported at both ends, or with hanging steps converging toward a circular well-hole in the centre. Fig. 34 shows an example of a solid-newel staircase of small diameter, such as are used in turrets. Each step is formed in one solid stone, as shown in (*c*),

with the circular portion on the inner end equal in diameter to the intended newel, as shown in (*a*), which forms, when the stair is built up, a continuous solid central newel, as shown in (*b*), and gives the necessary support to the steps. The outer ends are built into the wall. Sometimes, instead of a stone newel, a brick or stone cylindrical shaft *a*, Fig. 35, is formed, and the inner ends of the steps are built into this, making both ends rest on the walls. In staircases of large size, the central newel is omitted, and the stairs are formed with spandrel hanging winders, or wheel steps, built into the outer wall of the staircase and converging

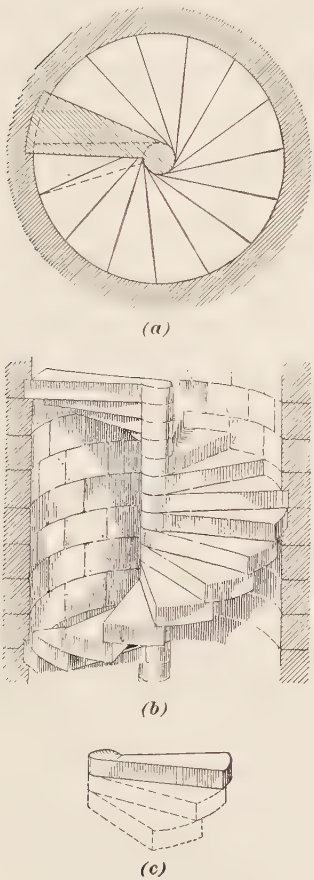


Fig. 34

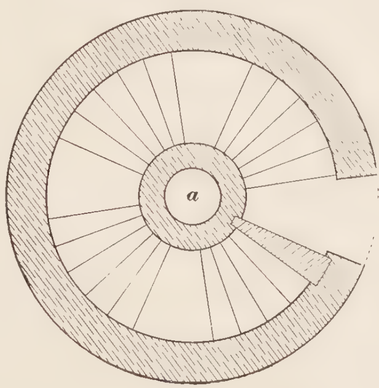


Fig. 35

toward an open circular well-hole in the centre; this method is known as a geometrical staircase. These steps should be inserted into the wall not less than 6 inches, but if the projection of the steps is considerable they should be inserted at least 9 inches. Wall handrails are desirable for these stairs, while for those with open wells a railing and handrail are also necessary on the well side.

MASONRY FIXING

SPECIAL JOINTS

35. Hoisting Apparatus and Fixing Tools.—As in many cases stones to be set in position for fixing on a building are much heavier than one or even several men can lift, special appliances for lifting and setting stones must be used. A description of the travelling cranes, gantry, pulleys, and various mechanical contrivances for lifting and moving stones and other heavy materials will be found in *Preliminary Building Operations*. The tools used by a mason in fixing stonework are very similar to those used by a bricklayer in laying bricks. The trowel is used to spread the mortar, plumb-lines and spirit levels are used to test vertical and horizontal lines, the square is used to set out right angles, and hammers and chisels are used to knock off rough projections and angles. A description of all these tools will be found in *Brickwork*, Part 1, so there is no need to describe them in detail again.

JOINTS AND CONNECTIONS

36. Kinds of Joints.—There are several methods adopted to give additional strength to the joints of masonry, other than that derived from the adhesion of the mortar and the weight of the stone; the most usual are by means of *joggles*, *cramps*, and *dowels*.

37. Cement Joggles.—To strengthen the joints and prevent lateral movement, it is usual to cut a **V**-shaped sinking in the corresponding ends of adjacent stones, as shown in Fig. 36 (*a*). After the stones are bedded, the cavity thus formed is filled with liquid cement, which, as it sets, hardens and forms a cement joggle. The cement is liable to stain the stone, and is best

suited for thick blocks, a slate or iron cramp being better suited for thin-bedded stones.

38. Cramps.—The slate and metal **cramps** used to bind stones vary in form. They are set in mortise holes cut in the stones, and then run round with cement or lead, as shown in Fig. 36 (*b*), (*c*), and (*d*). Iron cramps should be galvanized, to prevent corrosion as far as possible, for corrosion will, in time, split the stone, or at least discolour its surface; but this may be avoided if the cramp is completely bedded in cement. The use

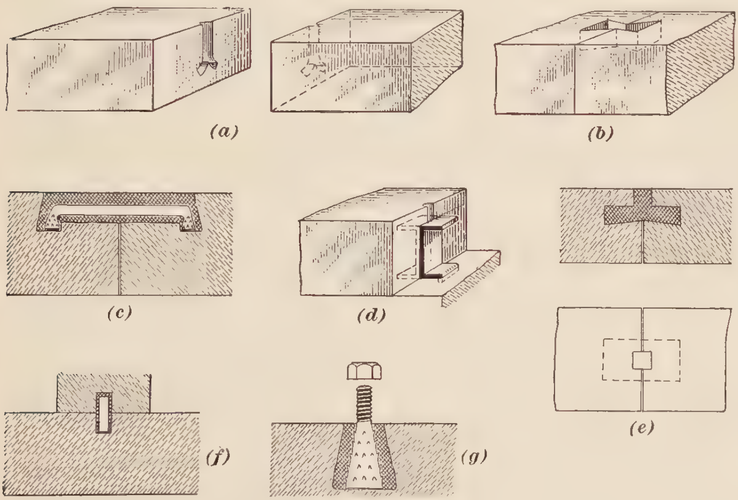


FIG. 36

of lead has also its disadvantages, as galvanic action may be set up through moisture and the iron become gradually eaten away. Copper, though more expensive, is the best material for cramps used in masonry. A form of cramp known as a **lead plug** is shown in Fig. 36 (*e*). Holes are cut in the ends of adjacent stones, as shown, and a small opening is left at the top into which the molten lead is poured.

39. Dowels.—**Dowels** may be of metal, preferably copper, or slate; they are mainly used to prevent lateral movement in stonework, as in Fig. 36 (*f*), and for fixing mullions and transomes of windows.

40. Rag Bolts.—When it is necessary to fix iron into stone, the method shown in Fig. 36 at (*g*) is usually adopted. The end to be fixed is forged out and the roughened surface is fitted into a sinking formed in the stone which is larger at the bottom than at the surface. Molten lead is then poured in until the whole space is occupied. When the lead is cool, the surface is hammered or *caulked* to allow for any shrinkage that has occurred in the cooling.

41. Special Joints in Stone.—While other materials are used to strengthen joints between stones, the same purpose is effected

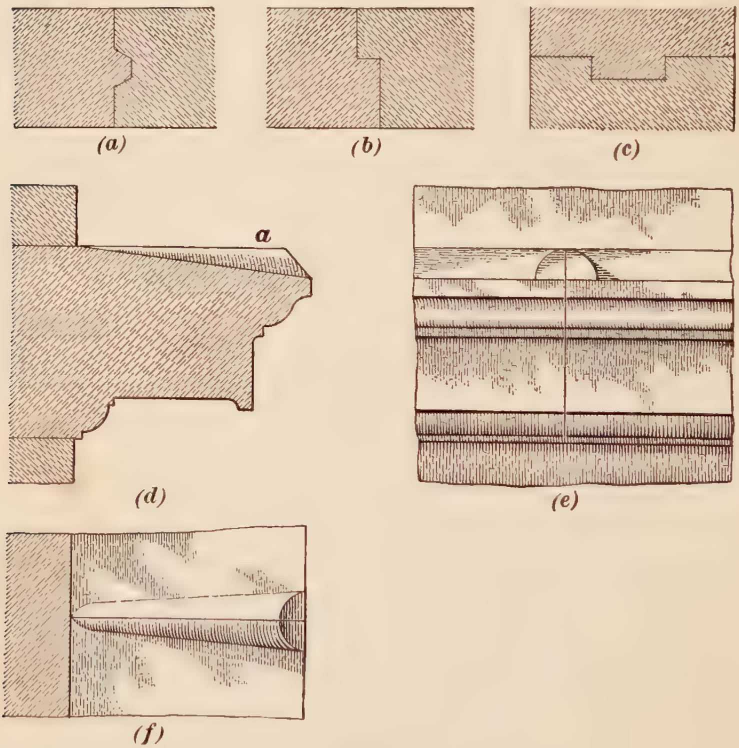


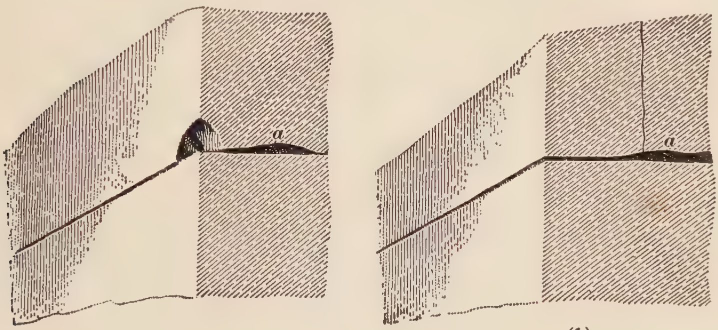
Fig. 37

in the process of dressing the stone itself. These are generally joggled, rabbeted, and tabled, as in Fig. 37 (*a*), (*b*), and (*c*),

respectively; but as these entail more labour and a waste of material, they are reserved for positions where such additional strength as they give is essential. A method sometimes adopted for the purpose of protecting the joints between the stones of a cornice or other similar member is shown in Fig. 37 (*d*), (*e*), and (*f*). View (*d*) shows the section through the cornice, (*e*) elevation of the joint, and (*f*) the plan of the joint. The object of this joint, known as a **saddled joint**, is to throw water away from the mortar or cement in the joint. Any water settling on the top of the joint *a*, Fig. 37 (*d*), will run down the slopes of the saddle and thus be thrown from the joint rather than allowed to soak into it.

DEFECTIVE METHODS OF FIXING

42. Faults in Dressing Stone.—The common faults of cut stone are coarseness and poor workmanship. In dressing stone, builders will often avoid any work beyond that necessary to make the material barely acceptable by the architect. Frequently, the ends of cornices, string-courses, etc., will not properly match.



(*a*) (*b*)

FIG. 38

It should be strictly required that the utmost care is taken in cutting all similar pieces to the same pattern and that abutting surfaces are closely dressed, and stones having uneven beds and untrue or winding faces will be rejected. The most common defects in rubble masonry are the failure to bring stones to an even bearing, the leaving of large vertical openings between

several stones, a lack of careful bedding and jointing, and the using of insufficient or poor mortar. A stone with a hollow bed cut in it, as shown at *a*, Fig. 38 (*a*), should never be used in a wall, for when the mortar shrinks, the stone will bear only at the edges and is liable to spall, with the result shown in the illustration. If not closely watched, careless masons are tempted to cut stones in this manner, as it is much easier than cutting them to a true bed. Another improper method often carried out by masons is to cut the stone as shown in Fig. 38 (*b*) and underpin the back with spalls. This practice is also liable to lead to disaster, as the stone may split as shown at *a*. Rusticated joints are used in the basement and lower stories of tall buildings to lessen the liability of spalling in the lower courses of stone.

43. Faults in Setting Stone.—The principal faults that occur in setting are in not getting an even layer of mortar between the stones or in getting small pebbles mixed in the mortar, both of which may tend to make the stone out of level. Care should also be taken to see that the stones are bedded in their proper position as regards projection from face of wall.

44. Patching.—When a piece has been broken from a stone, **patching** is often resorted to. Instead of using a new stone, the old one is patched by gluing on the spall with shellac and the joint is hidden by rubbing stone dust over it. Rain, however, will wash out the shellac. There are times when a patch is allowable, as, for example, when a new stone cannot be had without great expense and delay. In such a case, the architect may permit patching to be done, but care should be taken to put on the spall by inserting it, when possible, in a square hole, or dovetailing it in such a way that it will not become displaced.

CARE AND PRESERVATION OF STONEWORK

45. Cleaning Down.—One of the last processes to be gone through when a stone wall has been completed is that of **cleaning down.** This may be done by scrubbing the stonework with a brush dipped in water containing muriatic acid, the proportions being about 20 parts of water to 1 part of acid. For cleaning granite and limestone, wire brushes are used, but for sandstones

and other soft stones, stiff bristle brushes usually serve the purpose. The stonework should be scrubbed until all mortar stains are removed. The sand blast, worked by either steam or compressed air, does the work of cleaning walls very effectively and rapidly and is frequently used for restoring old work; it removes the outer layer of the discoloured stone, and leaves a fresh, bright surface. Even fine carvings have been very successfully cleaned by this method. Steam is often used for this purpose. It is passed through a small nozzle under a high pressure and rapidly removes all dirt and stains.

46. Protection of Stonework.—All masonry should be protected, during construction, from the effects of frost, and if the work is delicate in character, it should be protected from accidental injury during carriage and after fixing. All salient angles and mouldings, sills and jambs, steps and staircases, liable to be damaged, should be carefully protected with wood until the building is completed; these protections are removed during the process of cleaning down. A mixture of lime and stone dust is frequently smeared over the surface of stone immediately after the block has been dressed, to prevent any stains during fixing; this is easily brushed off when cleaning down.

47. Preservation of Stonework.—The durability of masonry may be somewhat increased by covering the exposed surfaces with a preservative, but of the many preparations for protecting stonework none is cheap or satisfactory. Lead-and-oil paint is often used for this purpose, but, while it may be temporarily effective, it spoils the appearance of the stonework and requires frequent renewals, owing to the action of rain and other atmospheric influences. Boiled linseed oil is also sometimes used, but it darkens the colour of the stone. To apply the oil, the surface of the stone is first washed clean and dried; the wall is then covered with one or more coats of oil, and finally washed with weak ammonia, which makes the colouring more even. Oil thus applied will last 4 or 5 years. Another preparation consists of paraffin mixed with creosote, the whole being dissolved in turpentine. The purpose of the creosote is to prevent vegetable growths on the stone. Before applying the preparation, the stone

should be heated; the melted compound is then applied with a brush. It will penetrate some kinds of stone to a depth of $\frac{1}{2}$ inch. Sylvester's process consists in the application of two washes, the first composed of a hot solution of Castile soap in water, and the second of alum water, which is applied about 24 hours after the soap solution. This process has been found more or less successful when the stone is not subjected to great variations of temperature. A saturated solution of carbonate of barium has been used on stonework, with excellent results, but several applications of the solution are necessary and the process cannot be so well used on exposed surfaces. This solution is poisonous.

48. A solution known as *fluate* is extensively used. It is said to harden and preserve limestone in new work from decay, and to arrest further decay in old work. It does not alter the colour nor the apparent texture of the stone, but it hardens the face and makes the stone more durable. The surface of the stone is cleaned and the fluate put on with a brush in two coats or dressings, using for each as much of the solution as the stone will readily absorb. Another method, which has been used with good results, consists in applying a solution of silicate of soda or potash to the clean surface of the stone until it is thoroughly saturated. When this has dried, a solution of chloride of calcium is applied; this produces an insoluble silicate of lime and forms a waterproof coating. The best processes are undoubtedly those in which the applied material enters into chemical combination with the constituents of the stone, but it is well to avoid, as far as possible, the need for such methods by careful selection, and making sure that the stone used is the best for the purpose and from the best bed in the quarry selected. It is better not to use stone rather than build with one that is badly adapted for the purpose and which in a few years will begin to decay.

49. Inspection.—The architect should be very careful to have all the masonry work properly done during erection, both as regards the cutting and the setting of stones, for if an imperfect piece is once set in place it cannot be removed without considerable trouble and expense. All stones should be carefully examined so that no defective stones are used.

CARPENTRY

(PART 1)

TIMBER AND ITS USES

STRUCTURE AND GROWTH

1. A general knowledge of the growth, varieties, conversion, drying, and properties of timber is essential to the intelligent disposition and arrangement of this class of building material so as to secure the most stable and permanent construction.

2. Divisions of Trees.—There are three general divisions of trees, each being classified in accordance with its respective mode of growth: (1) The *exogenous*, or outward growers, in which the stem increases by the formation of annual layers deposited round the *outside* of the preceding layer; this class includes oak, chestnut, pine, etc. (2) The *endogenous*, or inward growers, in which the woody matter is formed on the *inside* of the stem; the palmetto tree is an example. (3) The *acrogenous*, or summit growers, in which the stem is produced by the lower stalks of the leaves growing together, such as tree ferns. The first class is the only one of practical interest to the carpenter.

3. Exogenous Growths.—In Fig. 1 is shown the microscopic enlargement of a section of the stem of an oak tree of 3 years' growth. It has three well-defined kinds of tissue: the pith, the woody layers, and the bark. At the core, or heart, at *a*, is seen the *medulla*, or pith, which is composed of cellular tissue, a net-like fabric of cells resembling a honeycomb; at *b*, the *medullary*

sheath surrounds the pith and is composed of spiral vessels and fibre ducts for the conveyance of the sap; this constitutes the inner layer of the first year's growth. At *c* are the *wood cells*, or fibre tubes, composing the successive annual layers, which are formed in a series of concentric rings; each annual layer, as shown at *1*, *2*, and *3*, is called an *annual ring* or *zone*.

There is a well-defined line of separation between each pair of zones. About one-half of the width of the zone is occupied by bundles of fibre tubes containing large sap vessels *h*, whose walls are pitted and dotted as shown, this portion representing the spring growth, while the remainder of the width is filled with fibre tubes of much closer texture, this portion representing the summer growth. In ash, chestnut, and oak, the vessels *h* are easily observed.

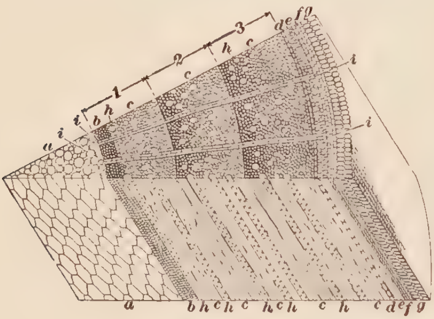


FIG. 1

The line of separation is caused by the suspension of the growth of the stem during winter. When the tree is young, the tissue is open and spongy and filled with various fluids, but in process of time, it becomes thickened and firm and the ducts close, the thickening of the tissue beginning with the layer first formed. For this reason, the best timber is secured from mature trees, as the fibres have then become compact and firm, and are less sensitive to changes of temperature when once well seasoned. Both young and second-growth timber are unfit for all purposes where strength and durability are required.

4. Heart Wood and Sap Wood.—Much difference as to strength and appearance exists between the mature, compact, inner layers of the *heart wood*, called **duramen**, and the layers of the *sap wood*, called **alburnum.** In the former, the fibres are firm and dense and possess a deep rich colour, while in the latter the fibres are open, porous, and filled with sap and usually have a pale colour.

The sap wood possesses little strength, and the sap it contains is largely composed of a sugary substance, which invites the attack of insects and hastens decay.

5. Annual Rings or Tree Zones.—When zones are visible, the age of a tree may be ascertained by counting them. Frequently, however, their growth is interrupted by severe frosts and other conditions, causing a line of separation. Several lines may be formed in one year, and thus lead to an erroneous estimate. That part of the tree which is more fully exposed to the sun will be found to have wider layers than the other part; hence, the pith, or heart, is seldom in the centre of the stem. Softwoods usually possess wider zones than the hardwoods, and it will be observed that much difference exists between the width of the zones in the same tree.

As in the animal kingdom there are three periods of existence, namely, infancy and youth, vigorous life, and declining vitality and decay, so also a similar series exists in the vegetable kingdom. When the tree is most vigorous, it produces the largest zones. In the oak, this occurs between the twentieth and the thirtieth year, after which its productive power is gradually lessened, and as it grows older the zones become smaller.

6. Cambium Layer.—Between the inside of the bark and the woody layers is found the **cambium layer,** as shown at *d*, Fig. 1, which consists of a cellular tissue like the pith, but contains, in addition to the cell sap, the rich life-giving secretion called *protoplasm,* without which the tree cannot live. This layer possesses the property of building up the woody formation by the product of ever-increasing cells, and only by the vital energy of this layer, also called the *thickening zone*, can the tree increase in diameter.

7. Composition of Bark.—The bark consists of three distinct layers. The **inner,** or **bast, layer** *e*, Fig. 1, is composed of woody fibres combined with a cellular tissue, which retains a flexible, rubber-like elasticity and allows it to expand as the woody layers are produced by the cambium. The **central layer** *f* is comprised of prismatic cells and tubes filled with juices, while the **outer layer** *g* is composed of a corky substance of cellular

structure. During the growth of the tree there is a continual distending and separating of the fibre and cellular tissue composing the bark, which is renewed and strengthened by means of the cambium layer.

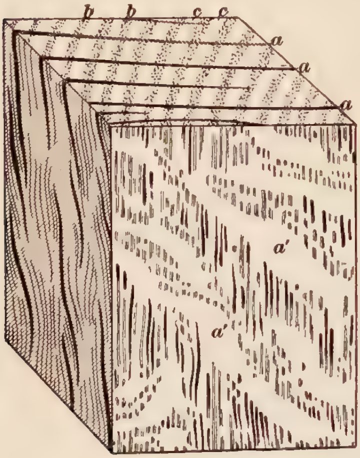


Fig. 2

8. **Medullary Rays.**—In the stem of many trees, spider-like lines radiating from the centre of the tree will be observed; these are called **medullary rays.** When they connect the pith to the bark, as at *i*, Fig. 1, they are called *primary rays;* but where they extend through only a portion of the stem they are called *secondary rays.*

These medullary rays, generally called *silver grain,* when exposed on the surface of the cut timber, consist of a series of vertical plates, or sheets. Originally of cellular tissue, they have become flattened by compression until they resemble sheets of mica; they are not, however, continuous vertically, but are buckled and present a serpentine outline, when exposed on the edge, as shown in Fig. 2. On the end-cut in the figure, the medullary rays are marked *a,* the porous fibres of the zones *b,* and the close or denser ones *c.* The appearance of the silver grain, or medullary plane, when cut nearly parallel with its direction is shown at *a'*; it is these medullary rays that give so much beauty to quartered oak. The rays are prominent also in beech and sycamore, but are not so well defined in birch, chestnut, and maple.

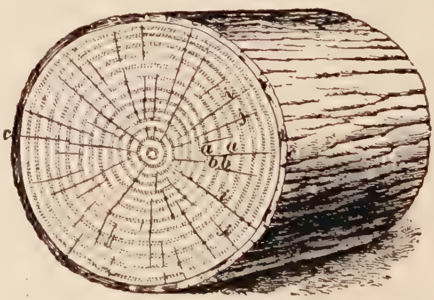


Fig. 3

9. Structure of the Stem.—The structure of the stem, as represented by the end of an oak or an ash tree of 13 years' growth, is shown in Fig. 3, in which the porous fibres or sap vessels of the coarser texture are shown at *a*; the closer texture at *b*; the primary medullary rays at *i* and the secondary ones at *j*; and the zone of the bark at *c*.

10. Conditions Affecting the Quality of Timber.—Trees growing in the heart of the forest are generally straight and tall, as it is necessary for their leaves to receive sunlight and air sufficient for vitalizing the sap; the lower branches of these trees last only a few years, when they die and fall off. On the edges of the forest, however, the lower branches of the trees remain alive and active, so that timber cut from such places is knotty and cross-grained, while that cut from the inside trees is clear and straight-grained.

11. Influence of Soil on Timber Growths.—The soil in which timber is grown exercises an important influence on its quality; where damp and marshy, the fibre is of a light, spongy character, the excess of water preventing the healthy action of the sap in forming firm and compact wood. Such soil is better adapted to the growth of light woods, as willow and whitewood. The hardwoods thrive best in dry, clayey soils, while those of the pine group are best developed in sandy soils.

12. Effect of Windstorms on Timber Growths.—Exposure to prevalent windstorms in one direction tends to produce a twisted, spiral mode of growth. Timber of this character has practically no value for building purposes, for the reason that when cut into planks or scantlings, the fibres run obliquely across it, and give it little or no strength.

13. The Bleeding of Timber Trees.—The bleeding of pine trees for their resin, a process to which only the long-leaf and Cuban pine are subjected, has generally been regarded as injurious to the timber. Both durability and strength, it was claimed, were impaired by this process, and in the specifications of many architects and large consumers, such as railway companies, *bled* or *boxed* timber was excluded. However, it has now been

proved conclusively (1) that bled timber is as strong as unbled if of the same weight ; (2) that the weight and shrinkage of the wood is not affected by bleeding ; (3) that bled trees contain practically neither more nor less resin than unbled trees, the loss of resin referring only to the sap wood, and, therefore, the durability is not affected by the bleeding process.

14. Causes of Wood Deterioration.—Trees are subject to excrescences and tumours, which lessen the value of the timber. These growths may result from the defective nature of the soil, from the attacks of animals by gnawing, or from insects that bore into the fibre. An excess of sap in some parts of the tree shows on the outer surface by the formation of pus, or matter, which expends the virtue of the sap and decreases the value of the surrounding fibre. This disease may spread, and ultimately cause the death of the tree. Trees are also affected by a brownish *rust*, which is caused by rainwater obtaining access to the interior by means of clefts or rifts in the bark, and which, by changing the character of the sap, reduces the wood to a powder. Trees are also subject to the attacks of innumerable destructive insects which deposit their eggs in the clefts of the bark, so that the grubs when hatched may be able to feed on the juices found in the sap wood. If it were not for the warfare waged on these insects by birds, etc., and for the action of frosts and rains, tending to prevent their excessive development, few trees would reach a state of maturity and be able to furnish sound, solid timber.

Where timber has been attacked by insects, the part affected, as well as the adjacent fibre, is rendered entirely useless for building purposes. Where the stem of a tree is regularly formed, and shows a perfect bark, free from rifts and excrescences, there is every likelihood of its producing perfect timber.

15. Cup Shakes.—In the body of sound, healthy trees there often occur circular seams, or cracks, where the layers have become separated from one another ; these cracks are said to be caused by the action of violent windstorms on the stem of the tree during the formation of the woody layers, and are called **cup shakes.** They generally occur near the base of the stem,

and in some cases can be detected in the standing timber by an abnormal increase in the bulk of the stem.

Where cup shakes occur, as at *a*, Fig. 4, there is much waste in cutting the material; but where the shake is short, as at *b*, the loss is not great. Sometimes, circular bands occur in the stem, in which the wood is of a softer and more spongy character than the surrounding layers, and which, in some cases, show signs of incipient decay. This condition is assumed to be caused by the action of sharp frosts on the rising sap in the newly formed layers. When timber presents this appearance, it should be immediately rejected, as it will be short-lived and will soon decay.

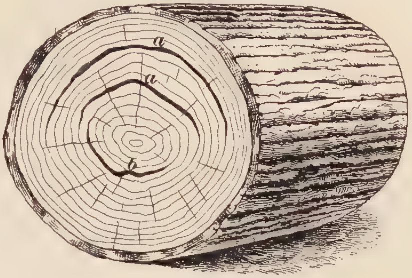


Fig. 4

16. Heart Shakes.—**Heart shakes,** sometimes called **star shakes,** are rifts, or cracks, which radiate from the centre of the tree, as shown at *a*, Fig. 5. They are common in nearly all classes of timber, and are caused by the shrinkage of the layers, incidental to loss of vitality. After the period of maturity has been passed and decline has begun, the outer rings, being more active, derive their nutriment by absorbing the juices from the heart wood, thus causing a gradual but sure loss of its strength and virtue.

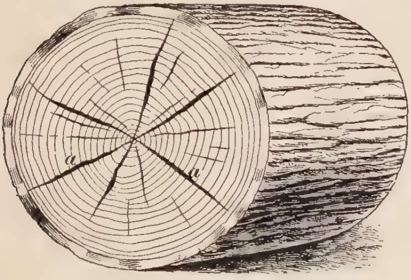


Fig. 5

17. Rind Galls.—Lumpy swellings making the grain irregular and causing an irregular grain are known as **rind galls.** They are due to the growth of new layers over a wound, made by the attacks of insects, or more generally by the lopping or breaking off of a branch.

FELLING, CONVERTING, AND SEASONING

FELLING

18. For the production of building timber, trees should not be felled until they have attained mature growth; but the felling must not be delayed until the tree shows signs of declining vitality, because the timber has then begun to lose its elasticity and firmness and gradually to become crisp and brittle. The best period of the year for felling trees is that in which the sap has ceased to circulate; consequently, midsummer and midwinter in temperate climates and the dry season in tropical climates are considered the most suitable periods for felling. Felled trees should be roughly squared so that the air may have free access to the wood.

CONVERSION OF TIMBER

19. The carpenter is seldom required to use timber in the round form given to it by nature, unless, perhaps, in the construction of rough and rustic work. Round timbers are, however, used in constructing pile foundations, and for props and supports when shoring buildings, the term *shoring* signifying a temporary disposition of timbers to afford support and rigidity to any mass or structure, but, specifically, where alterations of original conditions are being effected. They are also used in scaffolding.

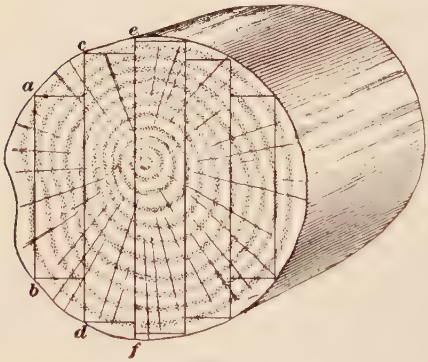


Fig. 6

Where timber of variable widths, but of equal thickness, is desired, the log would be converted into planks, as shown in Fig. 6, by a series of saw cuts, as *a b*, *c d*, *e f*, etc., parallel with each other, the edges of the planks being afterwards squared

by cutting off the *waney*, or bevelled portions, which formed the curved surface of the tree.

Where a large number of planks of uniform width are required, the end of the log would be marked as shown in Fig. 7, and the cuts made on the lines indicated. The portions *a*, called slabs, are usually waste material, although sometimes they are used for building fences and for finishings on rustic cottages, etc.

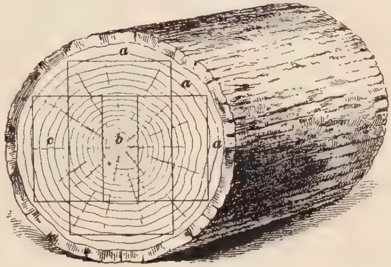


FIG. 7

20. Tendency of Planks to Curl.—The manner in which the annual rings of growth are disposed on the end section of the plank has a great influence on its behaviour after it is cut from the log. During the process of *seasoning* the timber, or the drying and hardening of its fibres by the evaporation of the natural sap, there is an ever-prevalent tendency for the planks or boards to curl and warp. This is particularly true if the process is too rapidly enforced and special care is not taken to pile the material so as to allow free circulation of air, and at the same time have it stacked so that its weight will help to keep the boards flat. The cause of this tendency to curl will be understood by referring to Fig. 8, in which are shown the end sections of two boards cut from different portions of the tree. At *a* it will be observed that the annual rings are nearly at right angles to the surfaces of the board, while at *b* they cross the surfaces obliquely and become nearly parallel with the faces. After the boards are cut and have begun to dry, owing to the evaporation of the sap,

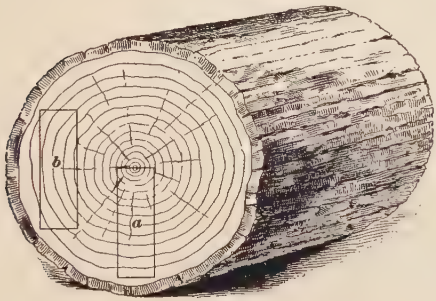


FIG. 8

the sap ducts and fibres begin to contract and shrink. The form taken by the board in shrinking will be governed by the length of the annual rings on the section. At *a* the rings are practically of the same length, and as the medullary rays are nearly parallel with the surface of the board, the faces will remain straight and true across their width. At *b*, however, the inner ring is shorter than the outer one; hence, the outer one will shrink more, causing the surface farthest from the heart of the tree to assume a concave form. This effect is further increased by the fact that the nearer the heart, the more dense and mature is the fibre, so that portions cut adjacent to the heart shrink less than those farther away from it.

Where a tree is twisted in its growth, that is, where the fibres seem to twist spirally round the stem in the height, it is impossible to cut from it boards that will not warp and wind, both while they are seasoning and whenever affected by changes in temperature.

As has been shown, boards having the annual rings disposed as at *a*, Fig. 8, are less liable to shrinkage and curling, and if the timber is rich in medullary rays, the element of beauty is also enhanced; further, such boards, having only the edges of the laminations exposed, wear better and more evenly than where the leaf-like figure of the grain is shown on the surface, as it would be in the case of the board *b*.

21. Methods of Sawing.—In order that as many boards as possible may be obtained from the tree, and at the same time that the boards may possess as handsome a grain as possible, the logs are first cut into quarters and then reduced to the required sizes. This method is shown in Fig. 9, where *a b* and *c d* are lines showing the first saw cuts. These cuts divide the log into four quarters,

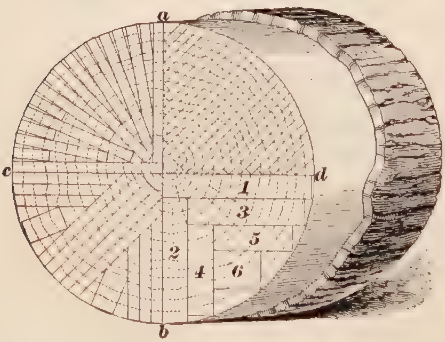


FIG. 9

each of which is then sawn into plank by some one of the methods shown.

A quarter sawn as shown from *a* to *c* would give by far the best results, as the annual rings cross the plank nearly at right angles to its face; also, the medullary rays, being parallel with this face, will exhibit the lines of the silver grain, so sought and admired in quartered oak. This method, however, is not economical in material, and more time and attention are required to divide it than is the case with any of the other methods. The waste of material exceeds 25 per cent., and, though this waste can often be utilized, it is usually counted as loss in estimating the amount of timber that can be cut from a log. The time required to reduce this quarter to plank is 30 per cent. more than for the quarter *c b*, and 50 per cent. more than for the quarter *d a*. Therefore, wood quartered in this manner would be expensive. In actual practice, much of the quartered oak is cut on lines similar to those shown from *b* to *d*, planks *1*, *2*, *3*, and *4* being further sawn into boards and the rest cut for flooring, posts, etc.

22. The method used in sawing the quarter from *c* to *b* is, as already stated, much more economical in time than in the case of the quarter *a c*, though the waste of material is about the same. The waste pieces, however, are much larger and can generally be utilized to better advantage. This is a usual method of cutting hardwood logs, and timber produced in this way is used for all ordinary high-class work in carpentry and joinery, especial attention being given to the position each plank occupied in the original log, according to the purpose for which it is required.

The method of sawing illustrated in the quarter from *a* to *d* can hardly be called quartering in the sense that the results of that term are considered. It is somewhat of an improvement on the method of bastard sawing, shown in Fig. 6, but there is only one-fifth of the finished timber that presents the advantages of beauty and durability secured by either of the two former methods of sawing, and this fifth is generally selected by the dealers, and classed with the plank produced by the middle

cut of the section from c to b. The other four-fifths is used almost entirely in cheap furniture and for the interior finishings of houses, where the terms oak floors and hardwood finishings sound very well in the description, but refer to details that would give better service if constructed of pine or spruce reduced from a properly sawn log.

The method shown at $b\ d$ is for securing large pieces, and the heavy planks are cut in the order that their end sections are numbered. Numbers *1* and *2* are the choice pieces, and should always be selected for situations where warping or twisting would be particularly undesirable.

23. Market Forms of Timber.—The following is a list of the principal forms into which softwoods are converted for the market :

A **log,** or **stick,** is the trunk of a tree after it has been felled and the branches have been taken off.

A **balk** is a log roughly squared into shape by an axe or saw. It is sometimes called *whole timber.*

A **plank** is a squared piece of timber generally sawn from balk. It ranges from 2 inches to 6 inches in thickness, is 11 inches and upwards in width, and from 8 feet to 21 feet long.

A **deal** resembles a plank, but is less than 11 inches and more than 7 inches wide, and is not more than 4 inches thick ; *whole deals* are 2 inches or more thick, and *cut deals* less than 2 inches thick.

A **batten** is similar to a deal but is only 7 inches or less in width, and generally between $1\frac{1}{2}$ inches and 2 inches thick.

A **quartering** is squared timber varying in size from 3 inches by 3 inches to $4\frac{1}{2}$ inches by 4 inches.

SEASONING TIMBER

24. Seasoning, or the drying out of the sap in the woody fibres, reduces the material by shrinkage to the least dimension it is ever likely to have, thus permitting the joints in construction to remain close and tight ; and also it increases the strength. All kinds of timber are about twice as strong when thoroughly

seasoned as they are in the green state. The process of evaporating the sap is effected after the timber is converted into commercial sizes, such as squared timber for framing purposes, planks, boards, etc., by two methods, known as *natural seasoning* and *artificial seasoning.*

25. Natural Seasoning.—In the **natural-seasoning method,** the material is placed in the open air in stacks, with narrow strips between the layers ; a free circulation thus takes place throughout each pile, and the timber remains in this position for from 2 to 4 years, according to its ultimate purpose. One year is considered adequate for joists, studs, matchboarding, and other ordinary framing material, while work intended for finishings, doors, sashes, and other products of the joiner's skill, should season for 2 years, or even more, according to the class of material.

26. Water Seasoning.—In this method the timber as soon as converted is wholly immersed in water, it being held down under the surface by chains or other means. A great part of the sap is thus washed out. The timber is allowed to remain in water for from 2 to 4 weeks, after which time it is carefully dried in the open air. Warping and cracking of the finished timber are less likely when water seasoning has been adopted, but the material is generally less strong and more brittle than timber that has been seasoned in the ordinary way.

27. Artificial Seasoning, or Stove or Kiln Drying.—The chief advantage of **artificial seasoning** is that the process occupies a few weeks, whereas natural seasoning in air may occupy from 1 to 4 years. Another advantage is that it produces material which is more likely to stand without shrinking in rooms artificially heated to high temperatures. *Softwoods* should primarily be air-seasoned for several months, but are usually put in a kiln as soon as cut up. One-inch boards are thus dried in from 10 to 14 days, the slower the better, as rapid drying is likely to separate the fibres by generating steam in the evaporating sap. *Hardwoods* should be air-seasoned for at least a year

before being placed in the kiln, and 1-inch boards should be allowed to remain there for 2 or 3 weeks.

Kiln drying is effected by stacking the timber in chambers, or kilns, within which a circulation of air is maintained at a temperature of about 140° F. and at a speed of about 40 miles per hour. Vacuum pumps are used to produce this rapid circulation and to remove the moisture as it evaporates from the boards. The timber is stacked in the manner already described, except that the strips between the layers are a little larger so as to admit of a better circulation of the hot air. Many authorities hold that kiln-drying weakens timber, reducing its elasticity and rendering it less fit for its ultimate purpose.

28. Moist-Air Kiln.—A modern form of timber-drying kiln is the **moist-air kiln.** By keeping the air moist, the timber dries more evenly and with less warping than would be the case with dry air. The moist-air kiln consists of a long building with a door at each end. The green timber is wheeled in on trucks at one door of the kiln, and is gradually moved along to make space for more incoming timber, until it finally emerges from the opposite door completely dried. The air, heated by steam pipes under the floor, enters between the tracks at the discharging end of the kiln, and it travels slowly through the kiln by natural draught, being discharged through openings near the end where the green timber enters. This air absorbs moisture from the timber at the discharging end of the kiln, and, by the time it reaches the opposite end, is quite moist. Timber takes about 1 or 2 weeks to go through the kiln, according to its size and greenness.

29. Dry Shrinkage.—Timber kiln-dried at a temperature exceeding 200° F. lacks the toughness and elasticity retained in the air-seasoned material, has a greater affinity for atmospheric moisture, and is often subject, especially in the softer woods, to what is known as **dry shrinkage** ; this is a shrinkage caused by the gradual closing together of the cell walls from which the moisture was evaporated in the kiln, leaving the cell in a vacuous, or hollow, condition. This dry shrinkage does not take place until after the material has been worked, and,

regardless of the position of the zones or annual rings, the wood becomes concave on its freshly cut surface.

The cause of this shrinkage is that the outside, or surface, tissue of the material is dried first and thus forms a sort of casing, or crust, which holds the inner fibres in position, and when this surface is removed by means of a saw or a plane, the interior fibres, being thus relieved of their protecting casing, gradually close on the exposed side and cause the wood to bend or warp.

Shrinkage will also occur in weather-seasoned wood that is allowed to remain in one position for a long period without being cut or worked. Thus, the top of an old table will almost invariably become concave if it is planed off to get a new surface.

Good results are obtained by subjecting weather-seasoned boards of 2 or 3 years' exposure to kiln drying before they are used in a building, or immediately after they are converted into flooring, matchboarding, etc. Boards thus treated and kept perfectly dry thereafter can be used in the finishings of a building, and, if primed and painted or filled and varnished immediately after they are in place, a durable job can be assured.

DECAY AND PRESERVATION OF TIMBER

30. After timber has been converted from the log to planks, boards, etc., the greatest care must be exercised in stacking it, so as to prevent the attack of parasitic plants, called *fungi*. These constitute a lower order of plant life, which, instead of independently assimilating and digesting nourishment extracted from the soil, derive their nutriment from the organic substance of other plants. The conditions being favourable, the work of this insidious foe continues until the entire fabric is reduced to powder. The parasite attacks the living tree as well as cut timber, and in both cases the result is complete destruction.

31. Stacking or Piling of Timber.—Timber should be stacked in high-and-dry situations only, and should be kept well up from the ground on staging, strips being placed between the beams or boards so as to permit a thorough circulation of air round every

side of the timber. No vegetation should be allowed to grow under or round the pile, as it will create conditions favourable for the retention and germination of the spores of the fungi. The surface of the ground should be covered with ashes or gravel, which will prevent vegetable growth and also keep the surface free from moisture.

Timber deteriorates very rapidly in quality if it becomes heated, which may arise from the material being closely piled together or from being placed in a confined situation; in either case the sap is prevented from evaporating and soon begins to ferment, causing the fibre to show signs of decay. The decomposition of the fibre is also caused by alternate dampness and dryness; this is forcibly illustrated by the action on fence posts, which, although sound above and below the ground line, soon give way at the parts thus affected.

32. Decay of Timber.—Sound timber placed in a dry, well-ventilated position, or entirely submerged in water, should last for centuries. Old age is evident when the wood becomes weak and brittle. Decay, or rot, may be caused by the presence of sap, conditions that tend to the germination and attacks of fungi, and alternate wetting and drying of the material. Damp earth, damp walls, and contact with mortar hasten decomposition, and warm, humid air and lack of ventilation are also causes of decay. Timber cut from trees that have lost their vigorous growth either by disease or by old age is weak, brittle, and perishable. The decay in this case works up from the roots and forms rotten heart wood.

33. Dry Rot.—The disease of timber known as **dry rot** is caused by confining timber in a position where there is no circulation of air, which promotes a growth of fungus that eats into the fibres and reduces them to a powder. The fungus first appears like a frost, and then spreads in fine thread-like lace over the surface, eventually forming a vegetable-like growth with spreading leaves.

Dry rot occurs in joists and floors over warm, unventilated portions of cellars and spaces under the ground floor joists; in unseasoned beams and joists built solidly into walls; in heels

of trusses encased in box cast-iron shoes which prevent sap from escaping; in floor joists and sleepers embedded in mortar; in wall plugs driven into damp walls; in flooring covered by impervious material, such as oilcloth, linoleum, rubber tiles, etc., which prevent the access of air and retain dampness. Charring, tarring, and painting unseasoned timber also cause dry rot.

34. Wet Rot.—The condition called **wet rot** may occur in growing timber, being caused by rain entering it through cleavages and wounds in the tree; in piled timber, due to too long exposure outdoors and not being under cover; and in framework, posts, piles, and exterior woodwork subjected to alternate dampness and dryness. Exterior woodwork should be well air-seasoned before being erected, all joints and ledges being so formed as to prevent the lodgment of moisture, and it should then be protected by painting. Flushing verandas or other floors exposed to the weather with a hose rots them more quickly than does the action of rain, as in the former case a great deal of the water is forced into the joints of the floor. The woodwork in kitchens, laundries, and other places where much scrubbing is done soon succumbs to wet rot. As wet rot spreads and attacks the sound timber, the diseased portions should be cut out in all work where durability is required.

35. Methods of Preserving Timber.—In general, building-construction timber can be preserved for an indefinite time by giving attention to a few simple requirements. It is well to remember that timber requires plenty of pure, fresh air, which suggests that the spaces it occupies should be well ventilated; also, it should be kept as dry as possible, and, where exposed, it should have a coating that is impervious to moisture.

Enduring Work.—For enduring work the timbers should be thoroughly seasoned before being put in place. Thus, the sap will be evaporated, all valuable gums in the wood, by hardening, will become fixed, and fermentation is not likely to occur.

Joists Built into Walls.—Air spaces should be left round all beams and joists built into walls. A good plan is to insert slates on each side of the timber as the walls are built, pulling them out before the brickwork or masonry is corbelled over the spaces.

Posts in cellars should rest on stone or metal bases, at least 3 inches above the finished floor level.

Basement Partitions.—If made of wood, basement partitions should rest on dwarf brick walls, at least three courses above the floor level.

Ground or Basement Floors.—Spaces under wooden ground or basement floors should be well ventilated, and where the soil is of a clayey nature and retains moisture, the surface should be covered with cement concrete or a layer of broken stones and finished with a coating of hot liquid asphalte. This precaution is also necessary for walls where moisture is apt to rise up into the brickwork or masonry by capillary attraction and thus affect the woodwork.

Posts Set in the Ground.—Posts that are to be set in the ground should be made of well-seasoned material, and should either be charred by burning or be coated with coal tar, these processes closing the pores and preventing the entrance of moisture. A surer and more lasting method of preservation is known as *creosoting;* this is effected by carefully extracting as much as possible of the moisture and air contained in the pores of the timber and forcing in at a high pressure oil of tar, commonly known as *creosote.* If carefully carried out, the process renders the timber proof against dampness, worms, and insects. Posts should always be set in the ground *butt up*, that is, in a direction opposite to that in which the tree grew. By following this plan, it has been found that moisture from the earth does not ascend so readily. The sap valves in the wood open upwards from the root, and when thus reversed they prevent the moisture from ascending.

Floors Subject to Washing.—Floors that receive much washing, especially porch or veranda floors, should have the joints matched and well coated with white- or red-lead paint.

Woodwork Adjacent to Stonework or Brickwork.—Door and window frames, wainscoting, and finishings adjacent to brick and stone walls should also be well coated with paint similar to that just mentioned.

Porch or Veranda Posts.—Posts for porches or verandas should not be placed in direct contact with the floors, as rainwater and

water used for cleaning ascends the pores of the wood and causes decay. Several devices of various types are used to isolate posts from floors.

Outside Finishings.—The finishings used on the outside of buildings should be well seasoned. All joints should be carefully made, so as to prevent the lodgment of water; they should also be well painted before being put together. After the priming coat, all shakes and cracks should be filled with white lead and oil putty, and the entire woodwork should then be properly painted, repainting at least every 3 years.

Gutters.—Gutters should be regularly examined for leaks. When gutters are placed on the roof or are sunk in the cornice, much damage may be done to the roof before any defects are noticed. Where practicable, gutters should be so placed that obstructions, overflows, and leaks will do as little damage to the woodwork as possible.

CLASSIFICATION AND VARIETIES OF WOODS

VARIETIES AND USES

36. Classes of Wood.—Wood as a building material may be divided into two general groups; namely, the **evergreen, or softwood, class** and the **hardwood class.** In the first of these are classed all varieties of cone-bearing trees such as pine, spruce, etc. The hardwoods include oak, chestnut, walnut, ash, elm, maple, mahogany and a number of others. The expression *hardwood* is a trade name and does not necessarily imply that the wood is hard, but means that it comes from a tree not an evergreen.

The weight of timber varies according to the position it occupied in the parent tree; the nearer the root and the closer to the heart, the heavier it will be. In similar trees grown under different conditions of soil and exposure, there is often a difference of as much as 20 per cent. in weight. When timber is *green*, or newly cut, it weighs from 20 to 50 per cent. more than dry material.

SOFTWOODS

37. Subdivisions.—Softwoods are included under the general head of *fir timber.* Their specific names are generally indicative of the place of growth or port of shipment. They are also classified broadly as *pines* and *spruces*, the latter being a botanical rather than a trade distinction. *Pines* have long, slender leaves in clusters, thick woody cones, and fairly square trunks that do not taper much.

Spruces have short straight leaves attached singly to the stalk, long-shaped cones, and their trunks taper much more than do those of pines.

38. Northern Pine.—The material known as **Northern pine** includes *Norway pine, Baltic pine, Scotch fir,* etc. The Northern pine is common to Scotland and the Northern parts of Europe, and the timber which it supplies is distinguished by the name of the port whence it is shipped. It is extensively used for all building purposes. The timber in balk is obtained chiefly from the ports of Dantzic, Memel, and Stettin in Prussia, St. Petersburg, Archangel, Onega, and Riga in Russia, and from ports in Norway and Sweden ; the timber obtained from these latter countries is of smaller dimensions and inferior in quality to that obtained from Prussia or Russia. When converted into planks, deals, etc., Baltic or Northern pine is described as *red* or *yellow deal.* In some cases, timber is exported from the above-named ports only in balk, but in the case of most of the Prussian and Russian ports it is converted before being exported. Baltic pine varies considerably in colour, but is generally of a reddish or brownish yellow. In general, the best quality has a clean, fairly close and straight grain and contains sufficient resin to make it durable. It is fairly free from knots, which, when they do occur, are, except perhaps in the case of Petersburg timber, generally live ones. A *live* knot grows with and forms part of the surrounding wood ; whereas a *dead* knot has become detached from the surrounding fibres and, when the timber is seasoned, may get loose and fall out. The varieties having the most resin are the hardest and toughest, and therefore the most suited for joists, beams, etc.

39. Red Pine.—**Red pine,** known also as *Canadian pine*, is obtained from a large tree growing extensively in the neighbourhood of the St. Lawrence River. It is similar in many respects to Baltic pine, but is paler in colour and not quite so heavy.

40. American Pine.—In England, **American pine** is known as **yellow pine** and in America as **white pine.** It is obtained from a tree common in the northern part of the United States and Canada. It is of a pale yellow colour, light, soft, and straight grained, and is used chiefly for joinery finishings of a durable but inexpensive character. For carpenters' work it is not to be recommended, except in a very dry atmosphere, for it quickly succumbs to moisture, and for that reason is not much used by carpenters in Great Britain. As a material for patternmaking it has no equal, and its power of holding glue renders it invaluable to the joiner.

41. Pitch Pine.—**Pitch pine,** also known as *hard pine, long leaf pine,* and *Georgia pine,* is a large forest tree growing along the southern coast of the United States. Its annual rings are smaller than those of the American pine, and have a dense, dark-coloured and resinous summer growth, which gives the wood a well-marked grain. The wood is hard and strong, and, under proper conditions, very durable. Its crushing resistance is higher even than that of some hardwoods, so for heavy framing timbers, beams, and floors, it is most desirable; on account of its grain it is sometimes used for interior finishings. The only reason why it is not more largely used for joinery finishings is that it contains rather a large amount of resin, which quickly escapes when the timber is cut, and leaves the surface with a tendency to split or show up unevenly.

42. Cuban Pine and Loblolly Pine.—Two woods that are very similar to pitch pine, and, indeed, are often sold for it, are **Cuban pine** and **Loblolly pine**; these are, however, of a coarser grain than pitch pine.

43. Carolina Pine, or Short-Leaf Pine.—Another wood that greatly resembles pitch pine is **Carolina pine,** or **short-leaf pine,** but it is not so strong or so durable. In appearance

it is somewhat lighter, and the fibre is softer and contains less resin than the regular pitch pine; consequently it is less suitable for carpentry work.

44. Oregon Pine.—**Oregon pine,** known in Canada and other parts of North America as *Douglas spruce*, is the most valuable timber in the Pacific region for structural purposes. It is used greatly for piling and for temporary structures where long scantlings are required.

45. Kauri Pine.—**Kauri pine,** obtained from New Zealand, is of a whitish-yellow colour with a close straight grain. It is strong and clear and free from defects, and, owing to its straight grain and small liability to shrink compared with other pines, it is useful for masts and joinery work generally.

46. Norway Spruce.—**Norway spruce,** sometimes called *white fir* or *white deal*, is a variety growing in Central and Northern Europe. It is exported from Archangel, St. Petersburg, and Riga, generally as converted timber for rafters, joists, flooring, etc., for which purposes it is used extensively. The best kinds of this spruce are used for internal joinery finishings, but for this purpose it must always be selected and well and carefully seasoned. It is of a dull whitish colour, is liable to be knotty, and twists in drying.

47. American Spruce.—There are several varieties of spruce obtained from America, all of which are very similar, the chief varieties being the following. *Black spruce* grows throughout Canada and in the northern half of the United States. Its wood is reddish in colour, and, though easy to work, is very tough in fibre and highly desirable for joists, studs, and general framing timber. This wood is also greatly used for piles and submerged caissons and coffer-dams, as it not only preserves well under water, but also resists to a great extent the destructive action of parasitic Crustacea, such as barnacles and mussels. *White spruce* is not so common as black spruce, though when converted it can scarcely be distinguished from the latter. Its growth is confined to the extreme northern part of the United States and to Canada. *Red spruce* resembles both of the above, but is

slightly redder when cut. It is sometimes known as *Newfoundland red pine.*

48. **Hemlock.—Hemlock,** to some extent, resembles both pine and spruce in appearance, though inferior as a building material. It is yellower and coarser in texture than spruce, but not so red, resinous, or hard as pine. The wood is very brittle, splits easily, and is very liable to be *shaky*. Its grain is coarse and uneven, and though it holds nails much more firmly than does pine, the wood is generally soft and not durable. Some varieties of it are better than others, but in commerce they are so mixed that a large quantity of even quality is difficult to get. Hemlock is now used almost exclusively as a carpentry timber in America and is coming more into use every year, as pine is getting scarce. At present it is not used to any great extent in Great Britain.

HARDWOODS

49. **English Oak.**—The structure of the fibre and the large, thick, and numerous medullary rays make **English oak** especially prized as a material for joinery work and interior finishings. The silver grain and the high and durable polish which the wood is capable of receiving make it one of the most beautiful of woods. It is also the strongest of the British-grown trees and one of the most durable of woods used for building purposes. There are two chief varieties used, the common or *stalk-fruited* oak, on which the acorns have long stalks, and the *sessile-fruited* or *cluster-fruited* oak, on which the acorns grow in clusters on short stalks. The former is generally supposed to be more durable, to contain more silver grain, and to have a better figure than the latter. To obtain the best figure effects for joinery finishings, oak should be quarter-sawn. English oak is not kept in stock in large quantities by timber merchants, as it is comparatively rare.

50. **Baltic Oak.—Baltic oak** is obtained chiefly from Poland and Prussia and several varieties are exported, though in general characteristics they are all very similar. The varieties are

named after the ports from which they are shipped. Generally, the Polish and Prussian oaks are of good quality and free from knots, but are not so durable or of such fine figure as English oak.

51. Austrian Oak.—Austrian oak is obtained from Hungary and is of good quality, but it is more yellow than English oak, softer and more easily worked, and consequently is not so durable.

52. American Oak.—*White oak* is the hardest of the American oaks, and it grows in abundance throughout the eastern half of the United States. It furnishes a wood that is hard, cross-grained, strong, and of a light yellowish-brown colour. It is used for constructional purposes where great strength and durability are required, as in framed structures, shipbuilding, and also for interior finishings. *Red oak* is similar to white oak, except that the grain is finer and closer and the colour is darker and redder. It is also softer and is not so suitable for heavy constructional work. *Live oak* has about the same properties as white oak, but is generally in smaller sizes. It is principally used for shipbuilding and for durable heavy framework, and is not exported to any great extent.

53. French Oak.—French oak closely resembles the English oak in texture and grain.

54. Mahogany.—Mahogany is the wood of a large, handsome tree that grows in the West Indies, Central America, and the West Coast of Africa. Its colour, grain, weight, and hardness vary considerably according to the age of the tree and the locality of its growth. There is nothing in joinery work in which mahogany cannot be serviceably employed, cost being the only limit to its use.

55. Honduras mahogany, sometimes called *baywood,* has a rich, golden colour, is easily worked, but requires great care in seasoning. It does not warp or shrink much, but lacks the deep red richness and figure of the *Spanish mahogany* and has a coarser grain.

56. **Cuban or Spanish mahogany** is a dense, hard, strong wood, of very straight growth and close texture. It has small pores filled with a chalk-like substance, by which means it is distinguished from Honduras mahogany, and is rich brownish red in colour, with dark, wavy markings.

57. **Santo Domingo mahogany** is very rich and handsome. Its figure, or markings, may be curly, watered, or wavy, feathered, bird's eye, or festooned, and its colour is a deep, rich red with yellowish shading. The wood is strong and very resinous. It is usually cut into veneers, thirty to the inch.

58. **African Mahogany.**—Of recent years **African mahogany** has been used to a very great extent, and its use is becoming more and more necessary where a cheaper mahogany than Cuban or Honduras is required. It is of a brighter colour than those last named, and by timber merchants is said to be *flannelly*, that is, its surface cannot be got to that very smooth state so easily obtained in better class woods. It is used in the cheaper class of joinery finishings to a great extent, and is very often inserted when Honduras mahogany is specified, as it takes an expert to distinguish between a really good piece of African and some of the ordinary Honduras mahogany that is used. African mahogany is very liable to shakes, and in finishing soaks up the polish like a sponge. It can be obtained in large sizes, and is classified under the name of the port from which the logs are shipped. The best is obtained from Lagos and Benin, and a very inferior quality is shipped from Gaboon.

59. **Jarrah,** known also as *Australian mahogany*, can be used for almost any constructive purpose. It is of a brownish-red colour with a coarse grain and not much figure; consequently, it is not very suitable for joinery finishings. When properly seasoned it is very durable and is eminently suited for pavings, piles, and sleepers. A similar wood to jarrah is **karri,** which is obtained from Western Australia; it is more liable to crack than is jarrah.

60. **Teak.**—**Teak** is sometimes called *Indian oak* and is obtained from the South of India, Siam, and Burma. It is

generally considered to be stronger and stiffer than English oak, is of a deep brown colour, of straight grain, and is not easily worked. It is largely fire-resisting and very durable in damp situations. For the latter reason it is used to a considerable extent in shipbuilding, and for piling and dock work; it is also used in almost all positions where oak would be employed for internal work. It is oily and fragrant, and resists the attacks of white ants and wood worms. As it preserves iron, it is used for backing armour plates.

61. Green-Heart.—**Green-heart** is obtained in British Guiana and the West Indies. The heart wood is from a dark green to a chestnut colour and is sometimes nearly black. It is next to teak in its ability to resist the attacks of the white ant and worms and the ill effects of damp. This wood possesses a clean, straight, compact structure, is free from knots, is exceptionally heavy, strong, tough, hard, and durable, and receives a high polish. It is used for piles, the construction of piers and jetties, the posts of dock gates, and any marine construction or position under water.

62. Blue Gum.—**Blue gum** is obtained from Australia, and is somewhat similar to teak but of a yellowish colour. It is considered to be superior to English oak in hardness, strength, and toughness; it can be obtained in great lengths and is useful for heavy constructional work, piling, etc.

63. Beech.—**Beech** is the wood of a large forest tree growing in England and Scotland, the temperate parts of Europe, and in the eastern part of the United States. It is often used for piles, and in places where it will be constantly submerged. If subjected to alternate dry and wet atmospheres it rots quickly. It is hard and tough, and of a close, uniform texture, which renders it a desirable material for tool handles and plane stocks, a use to which it is often put. Beech is occasionally used for furniture on account of its susceptibility to a high polish, but is too brittle for very fine work requiring strength. The white and black varieties are those most commonly known, the latter being the more durable.

64. Chestnut.—Chestnut is found in England, the South of Europe, and in the eastern part of the United States. It is somewhat similar to oak, but has no distinct large medullary rays. It is exceedingly durable when exposed to the weather. Owing to the fact that it holds glue well, it is a valuable wood on which to veneer. It is used for fence posts and rails.

65. Ash.—Ash grows in Great Britain, Asia, and America. It is of a brownish-white colour, very tough and flexible, has but little sap wood, and is easily worked. It is durable if well seasoned and kept dry, but soon decays when exposed alternately to damp and dry atmospheres. It is used sometimes for furniture and cabinetwork, as an imitation of oak, but it is never so strongly marked in the silver grain as oak, and it tends, after a few years, to decay and become brittle.

66. Elm.—Elm grows in Great Britain, Europe, and America, and is found in several varieties, the chief being the common *English* or *rough-leaved* elm. The heart wood is a reddish-brown colour and the sap wood yellowish. The wood is very tough and fibrous, and suitable for work under water, such as piles, pumps, etc. Other varieties are the *wych* elm, found in the North of England, Scotland, and Ireland; and the *Dutch* elm. The colour of the wych elm is not so dark as that of the common elm, but the wood is straight in grain and durable.

67. American Elm or White Elm.—The North American elm is strong, tough, fibrous, and difficult to split, and is used for flooring, ladders, and piles. The heart wood is a light brown, and the sap wood a yellowish white, rather coarse-grained, and somewhat resembles ash.

68. American Walnut or Black Walnut.—One of the finest and largest timber trees peculiar to the United States is the **American walnut** or **black walnut**, the wood of which is heavy, hard, porous, and of a dark, purplish colour marked by a beautiful wavy grain. Strong, durable, and not subject to the attacks of insects, black walnut at one time was the most popular wood for interior decoration and fancy cabinetwork, but its present use is confined generally to small cabinetwork and gun stocks. The

irregular and knotted growths of the tree produce, in the wood cut from them, a beautiful, wavy, speckled appearance, called **burl.**

69. White Walnut.—A small species of walnut whose wood is of a light colour and possesses a strongly marked grain is known as **white walnut,** and in the United States as *butternut.* It is obtainable only in short lengths, and though soft and easily worked, it will not split readily, resists moisture, and remains comparatively unaffected by heat until the wood begins to char. It is not suitable as framing material, but is sometimes used in cabinetwork on account of its susceptibility to an extremely high polish.

70. Basswood.—The timber of the American *linden tree* is known as **basswood.** In colour, texture, and general appearance it strongly resembles pine, but it is much more flexible. On this account it is sometimes used for curved panels in furniture, interior decorations, and carriages. It has a great tendency to warp, and will shrink both across and parallel with the grain, rendering it undesirable in building unless strengthened by battens or a hardwood lining.

SELECTION OF TIMBER

71. Light framing material is usually selected from woods that are plentiful and cheap, while heavy framing should be formed, where practicable, from timber possessing both strength and durability in the highest degree. As the exterior finishings of buildings are subjected to the extremes of hot and cold weather and to wind and rainstorms, a durable material that can be easily worked and is least influenced by these changes should be selected. The fibres should be firm and elastic, without being brittle, and of sufficient toughness to avoid splitting when being nailed in place, and to avoid warping and twisting after being erected. Where wood is embedded in concrete or is buried whole or in part in the ground, the first consideration is that of durability. For floors subjected to heavy work, the wearing

quality is the first consideration. When interior finishings are to be painted, any sound material that will hold glue and stand well may be used ; but where the wood is to be finished in its natural colour, by varnishing or by waxing, its colour and texture will usually govern the selection.

72. Characteristics of Good Timber.—In selecting timber for building purposes, the principal points to be carefully observed are that it has straight grain, freedom from large or loose knots, wind and heart shakes, and the presence of the characteristics that indicate any of the diseases and imperfections of the fibre previously described. When cut, the sawdust should not be clammy or doughlike, but granular, or mealy, crisp, sparkling, and free from stringy fibres. The surface of the sawn material should be clean and lustrous, presenting a firm and bright appearance, and free from spongy or woolly fibres, which indicate lack of vitality. The heart wood should be sound and mature, and the sap wood, or layers next to the bark, should be entirely removed. The wood should appear uniform in texture, and when cut should smell sweet ; a disagreeable smell is a sign of decay. When the wood is planed, it should have a silky, shining surface ; the shavings should come off like ribbons and stand twisting round the fingers. When the surface appears dull and chalky and the shavings are brittle and short, it may be considered that the material lacks much of the virtue it should possess. Good material should be uniform in colour ; when blotchy or discoloured, it signifies a diseased condition, which may be due to defective development, or be caused by stacking the timber close together after it has been sawn. The black-and-blue streaks and patches which often occur in timber are the result of close stacking, which causes the sap to sour, or ferment. The defective pieces should be cut out, and only those portions which appear sound and perfect should be used in work where strength and durability are essential requirements.

73. Woods for Special Purposes.—The following list will serve as a guide in selecting and specifying the different kinds of woods for special requirements :

Partitions, Framings, etc.—The various kinds of pine and spruce that are most easily procured in the country in which the material is to be used.

Heavy Framework in beams, floor joists, roof trusses, etc., such as are used in warehouse and factory construction.—Blue gum, teak, oak, Oregon pine, pitch pine.

Window Sills.—Oak or teak.

Treads of Stairs.—Oak and teak in best work.

Floors.—Teak or oak, Baltic pine, pitch pine, Norway spruce.

Piles.—Oak, elm, teak, green heart, pitch pine, Oregon pine, Baltic pine.

Posts and Sleepers in the Ground, durable in wet situations.—Jarrah, oak, teak, chestnut, elm, black spruce.

Interior Joinery Finishings.—Mahogany, oak, walnut, kauri pine, American pine, pitch pine, etc.

Foundry Patterns.—Mahogany, American pine.

CARPENTRY

(PART 2)

JOINTS, FLOORS, AND PARTITIONS

PROVINCE OF CARPENTRY

INTRODUCTION

1. The art of carpentry consists of the theoretical and practical knowledge necessary to properly execute all classes of structural woodwork. The province of carpentry is most extensive, so the subject is generally qualified by prefixing a term that denotes the class or character of the carpentry implied; as house carpentry, bridge carpentry, or ship carpentry. Wagon making, carriage making, car building, etc., also partake of the principles and practice of the trade; but this instruction is limited to *house carpentry.* It will, however, include the essential features that define the anatomy of construction of which all classes of buildings are more or less composed, except those known as *fire-resisting structures,* in which the members are made of iron or steel.

2. The carpenter is distinguished from the joiner in that his efforts are directed toward the formation and disposition of the constituent parts of the building, or to such parts as have reference to structure only. His operations are connected with the stability and efficiency of the framework parts of the edifice, while those of the joiner are confined to encompassing

the framework with finished woodwork. The joiner does not commence his labours until the framework has been completed. Therefore, the strength and life of the building depend largely on the effective character of its carpentry. The work of the joiner may be entirely removed and yet leave the structure intact, as far as the anatomy of its form and arrangement is concerned.

3. Divisions of Carpentry.—The art of carpentry comprises three divisions, namely, *analytic, descriptive,* and *constructive.* All of these are incorporated in a successful structure. The first and second divisions are contained in the *theory* of carpentry, while the third constitutes the *practice.* The first division includes the analysis of the forces that generate the stresses in the framework, which is demonstrated by the laws of mechanics, and the disposition of the material for efficient resistance, which is regulated by a knowledge of the strength of materials. The second division defines the lines and methods deduced by geometric rules for setting out the work. The third comprises the manual operations of cutting, framing, arranging, and uniting the various timbers that constitute the structure. Carpentry, in the case of wooden structures, relates to the construction of the rough timber framework of the building in all its parts, from the foundation to the roof. In countries where buildings are largely constructed of stone or other material outside the carpenter's province, the carpenter's work is confined to the erection of all necessary scaffolding, sheds, etc., required by his own or other trades, the construction of floors, roof, wood partitions, and the furnishing of and general setting of all centres, templates, wooden lintels, etc., that may be required for arches, angular and moulded work, wall openings, etc.

4. Classes of Wooden Structures. Buildings constructed entirely of wood above the foundations, other than those of a temporary nature, are uncommon in the British Isles. In the British Colonies, tropical countries, and America, however, they are frequently erected and may be divided into two general classes: *braced-frame* and *balloon-frame structures.* A **braced-frame building** is one in which each piece of the structure is

carefully united by mortise-and-tenon joints while the angles are held rigidly by diagonal pieces. The whole skeleton is thereby made stiff and secure in itself before any of the covering material is applied. A **balloon-frame building** is one in which the timbers are simply butt-jointed and nailed together. It therefore depends greatly on the sheathing, or outer covering, for strength and stiffness. The fitting together of the several pieces of a structure demands a knowledge of the tools used by the carpenter for the working of timber and the making of joints. It also requires a knowledge of the proper kind of joint for each particular case. It demands an understanding of the conditions likely to arise which tend to render the joint more or less ineffectual, such as shrinkage, dry rot, or warping, and the ability to compensate or prevent any evil results that such conditions will entail.

CARPENTERS' TOOLS

5. As so many of the tools used by the carpenter are also used by the joiner, all the more ordinary tools are described here, rather than describing some here and some in *Joinery*, Parts 1 and 2. Strictly speaking, the carpenter's tools are confined to varieties of the axe, adze, saw, and chisel in edged tools, while the joiner uses these and the plane in its many varieties.

SETTING-OUT TOOLS

6. The principal tools used by a carpenter in setting out work are shown in Fig. 1. They consist of: The *compass* (*a*), which is used for dividing and transferring dimensions; the points can be fixed at any distance apart by means of the screw. The *square* (*b*), which is a strip of metal and a strip of hardwood fixed at right angles; it is used to set out right angles before sawing, etc. The *bevel* (*c*), which is of similar construction as the square, but has adjustable strips that can be set and fixed to any angle. The *plumb rule* (*d*), which is a straight narrow board about 5 inches wide with a lead plumb, or weight, on a line hanging down the centre; it is used in fixing work to ensure correct vertical lines.

The *marking gauge* (*e*), for marking lines parallel to an edge consists of a stem *a* from the underside of which projects the point of a spike *b*; the block *c* can be fixed in position by the wedge *d*. The *spirit level* (*f*) is used for bringing surfaces to a

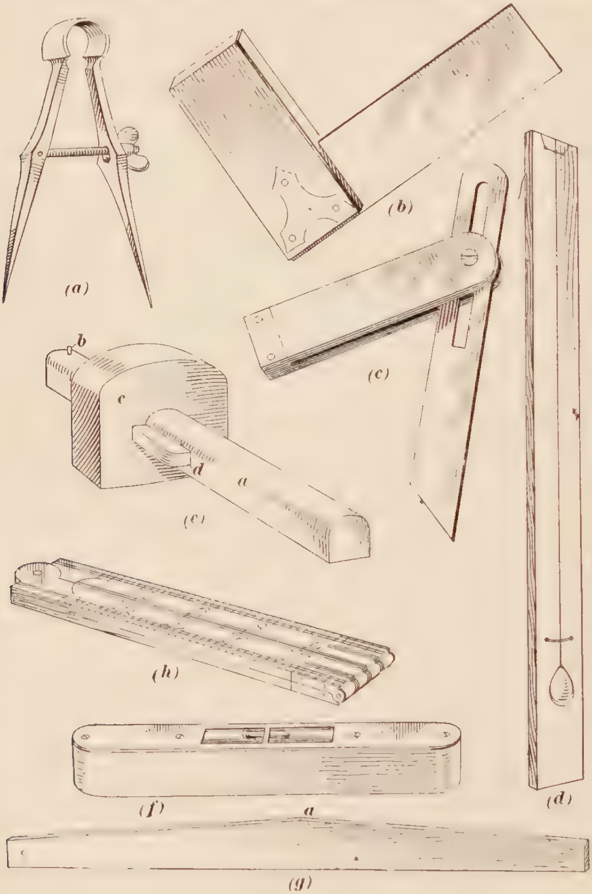


FIG. 1

correct horizontal plane. The *straightedge* (*g*) is for ruling straight lines and for proving the straightness of surfaces; the longer ones are made flat at *a*, to take a spirit level. The *rule* (*h*) is used for measuring; it is usually divided in eighths and sixteenths of an inch.

CUTTING TOOLS

7. The principal tools used in cutting wood by hand are shown in Figs. 2 and 3. In Fig. 2, the *axe* (*a*) has a steel head with one cutting edge; the length of the handle, or helve, which is of hardwood, varies according to the purpose for which it is required.

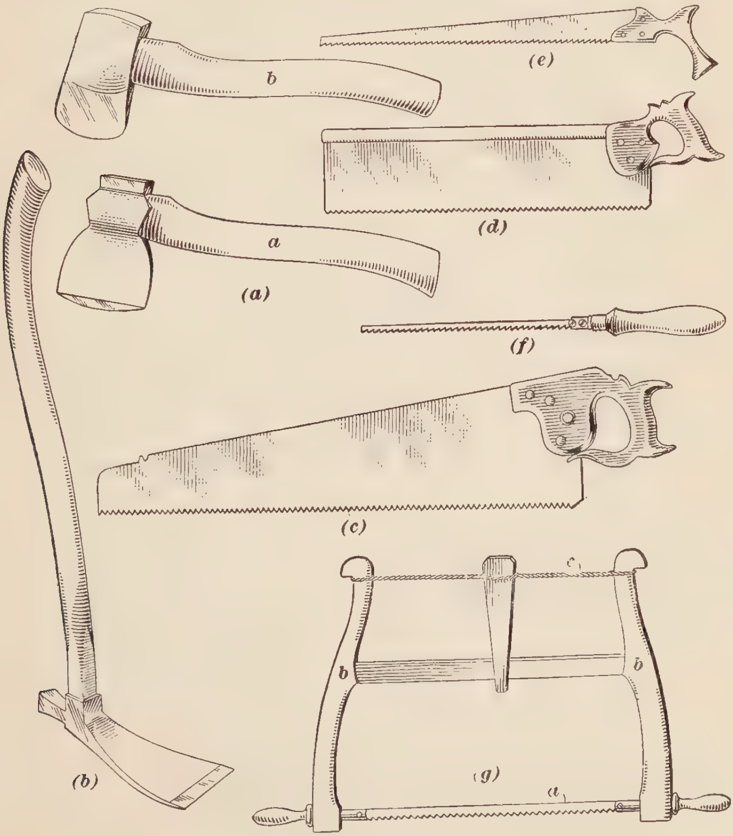


FIG. 2

Two varieties are shown, *a* is the English form and *b* the American The *adze* (*b*) is similar to the axe, but is used for roughly smoothing the surface of timber, the head is from 6 inches to 10 inches long. The *hand saw* (*c*) has a steel blade and a hardwood handle; it is

made in various sizes up to 30 inches long, and is used for long straight cuts. The *tenon saw* (*d*) is similar to the hand saw, but smaller and of thinner metal ; it cannot be used for long cuts on account of the stiffening band on the back of the blade. The *table saw* (*e*) is similar to the hand saw, but is smaller and narrower ; owing to its being thin and flexible it can be used to saw along a curved line. The *pad saw* (*f*) is used for sawing round sharp curves, such as keyholes. The *bow saw* (*g*) is for the same purpose as the pad saw ; the blade *a* is much thinner than in the other varieties and is strained in a wooden frame *b* and kept tight by the twisted thong *c*.

8. **Chisels.**—When it is necessary to remove part of the wood in the centre of the face of a block without disturbing the outside fibres, chisels are used.

The various types are shown in Fig. 3. They are : The *firmer*, or ordinary chisel, (*a*), which is of various widths of blade, all of rectangular section and with a bevelled cutting edge. The *gouge* (*b*) is similar to the firmer, but has a curved blade instead of a rectangular one. The *socket chisel* (*c*) is not a different variety as far as use is concerned, but the blade is fixed to the handle in a different manner ; it is very useful in cases where the fibres of the wood are likely to grip the blade very tightly. The *mortise chisel* (*d*) differs from the ordinary chisel in that the rectangular-sectioned blade is sharpened so that the short edge cuts, instead of the long edge ; it is used for cutting very narrow deep grooves, where the ordinary chisel of the same width would not be strong enough.

SMOOTHING TOOLS

9. **Planes.**—The *jack plane*, Fig. 3 (*e*), is the first plane used for removing the rough surface of the wood ; the cutting iron, or blade, *a* is fixed in position in the wooden body *b* by means of a wedge *c*. The iron projects slightly below the block and takes off a thin shaving from the wood. The *trying plane* (*f*) is larger and is used to obtain long true surfaces. The *smoothing plane* (*g*) smooths the surface of the wood after the jack plane and trying plane have made the surface true. The *rabbeting*

plane (*h*) is about as long as the smoothing plane, but is much narrower ; the blade, at the cutting edge, extends the full width of the body, across which it is set either square or slanting. The *plough* (*i*) is used for making grooves in the wood ; the cutting iron is from $\frac{1}{16}$ inch to $\frac{3}{4}$ inch wide. The *bullnose plane* (*j*), the cutting edge of which is very near to the front of the body, is useful for work situated in angles. With the *shoulder plane* (*k*) a finer finish is obtained than with the rabbeting plane. The

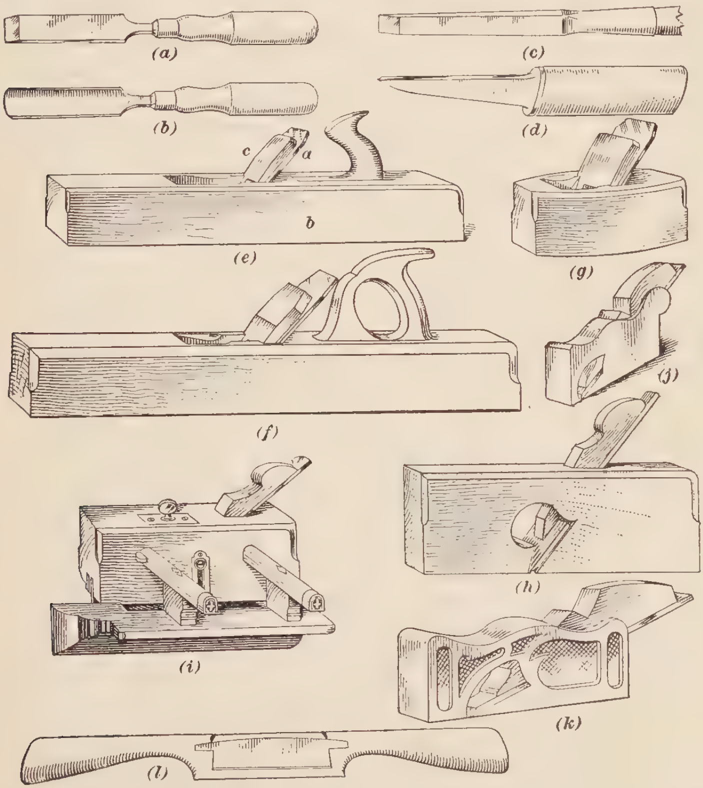


FIG. 3

spokeshave (*l*) is used to form rounded edges and surfaces, such as on wheel spokes. It consists of a small steel cutter set in a flat or curved hardwood handle, and when being used is held in both hands.

BORING TOOLS

10. The tools used for boring are generally well known. Those shown in Fig. 4 are: the *gimblet*, or *gimlet*, which is used for making small holes for screws, etc. The shell gimlet (*a*) is slightly tapered and easy to withdraw, while the screw, or twist, gimlet (*b*) cuts very easily and quickly. The *bradawl* (*c*) is used for making small holes; strictly speaking it is not a boring tool, as it does not remove any of the wood, but only forces the fibres apart. The *auger* (*d*) works on the same principle as the gimlet, but is much larger and is twisted by both hands. The *brace and bit* is a device for boring without the delay of changing hands

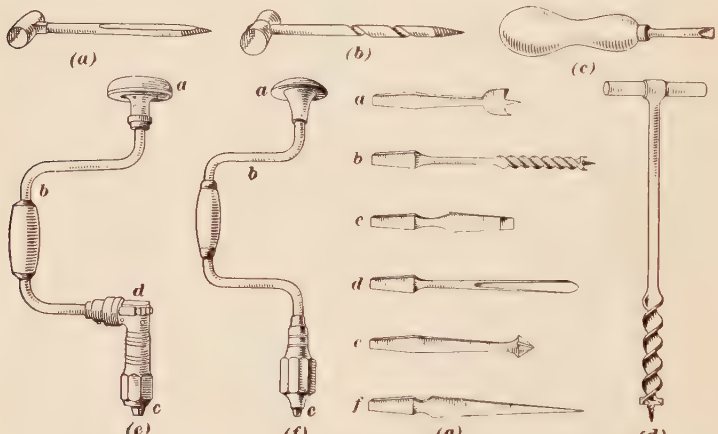


FIG. 4

that is required by augers and gimlets. Each of the braces (*e*) and (*f*) consists essentially of a head *a*, a movable crank *b*, and jaws *c* which firmly grip the *bit*. After fixing the *bit* in the jaws, the workman applies pressure to the head *a*, thus forcing the point of the tool into the material; at the same time he revolves the crank continuously in the same direction until the hole has been made. By means of the rachet *d*, in (*e*), holes can be bored in positions where a complete turn of the crank is impracticable. The bits (*g*) are of various types: the *centre-bit* *a* is used for shallow holes of large diameter; the *twist bit* *b* is used for deep

holes of small diameter. By using the bit *c* the brace can be used as a screwdriver, which work it performs very rapidly. The *shell d* is for boring holes from $\frac{1}{8}$ inch to $\frac{1}{2}$ inch in diameter, across the grain; the *counter sink e* is used for sinking holes for heads of screws, and the *rimer f* for enlarging holes.

MISCELLANEOUS TOOLS

11. The tools shown in Fig. 5 are too well known to need description. View (*a*) shows the hammer; (*b*), the mallet; (*c*), the screwdriver; (*d*), the pincers.

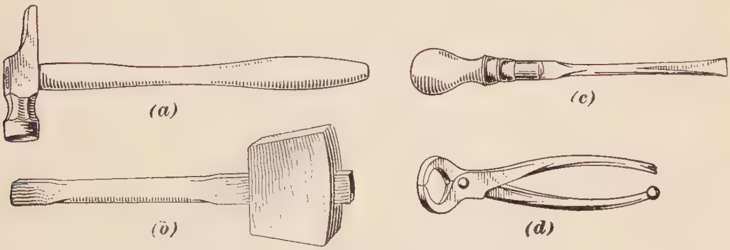


FIG. 5

JOINTS AND FASTENINGS

12. Classification of Joints.—Broadly speaking, **joints** may be divided into three groups: joints for lengthening, joints for bearing, and oblique joints. In making all joints, attention should be given to the character of the stress to which the joint will be subjected, whether *tension, compression, transverse stress,* or *torsion.* Provision must then be made for the joint to resist that stress, and at the same time fulfil any other conditions of utility that may be required of it. A member is said to be in **tension** when it is subjected to a tensile or pulling force; the tendency of this force is to lengthen the member. When subjected to a crushing or pushing force the member is said to be in **compression**; the tendency of this force is to shorten the member. **Transverse stress** tends to break the fibres of a member across their length. By **torsion** is meant the twisting stress on any member or material.

JOINTS FOR LENGTHENING

13. Lapped joints.—A lapped joint is one of the simplest forms of joint for the purpose of lengthening a beam or other tension member. In Fig. 6, the timber *a* is simply laid against the timber *b* and bolted up with the three bolts, as shown at *c*. Between the bolt heads, or nuts, and the face of the timber, in each case, a washer *d* should be interposed to prevent crushing or tearing the surface of the timber when the nut is being tightened. This makes a clumsy and awkward-looking joint, and should seldom be used except for temporary structures, but, apart from this, it is excellent for its purpose, and, by reason of the bolts, makes a strong joint for a tension member. If the beam is to resist compression, the joint is formed with straps, as shown in Fig. 7. The timber *a* is laid against the timber *b* and the straps *c*, *c* are securely fixed round the two timbers by means of the plates *d*, which are held in position and tightened up by the nuts *e*, *e*.

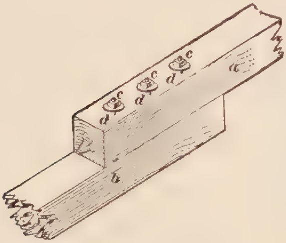


Fig. 6

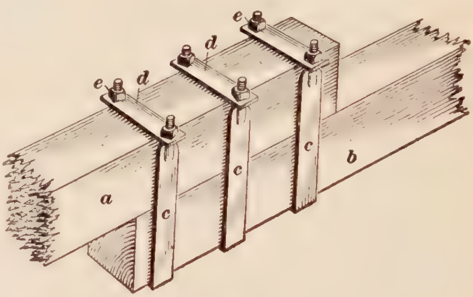


Fig. 7

14. Fishing.—A stud or post may be lengthened, or **fished**, as it is called, by the addition of an extra piece of the required length. The ends are cut square and the pieces secured together by nailing on the opposite sides of the stud two pieces of 1-inch board about 2 feet long, as shown in Fig. 8. For beams, fished joints are often

Fig. 8

made in plain and unimportant work by butting the ends of the timbers together and covering the joint with iron or wooden fish-plates, as shown in Fig. 9 (*a*) and (*b*). The joint shown in (*a*) is made between the two timbers *a* and *b* with an iron fish-plate *c* on top and a wooden plate *d* underneath, notched as shown to the two timbers *a* and *b*. These plates are held securely in position by iron bolts *e*; the nuts screw upon the under side. This joint is seldom used, as a considerable amount of material is wasted in its construction. A similar joint, and one more often used, is shown in (*b*), but wooden fish-plates and hardwood keys are used. In this view *a* and *b* are the two timbers to be joined and *c* and *d* are the wooden fish-plates that are placed at the top and bottom of the joint. Spaces have previously been cut in the plates and in the beams for the insertion of hardwood keys *e*, *e* which strengthen the joint. The whole is then securely bolted together by means of the iron bolts *f*, *f* which can be tightened up from one side by means of nuts. The keys *e*, *e* are inserted to assist the bolts so that when the tension stress is put upon the beam the joint between the two ends where butted together will not open. For a similar reason the iron fish-plate shown in Fig. 9 (*a*) is turned into the beam at its ends.

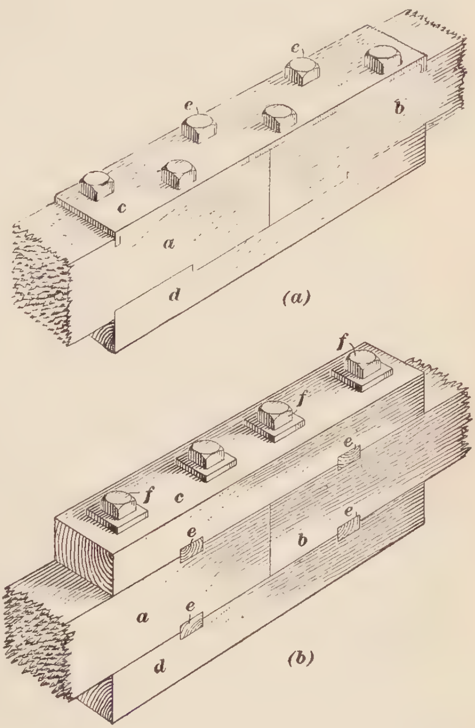


FIG. 9

15. Scarfing.—Where the joint will be subjected to compression or tension, or both, but at the same time must preserve an appearance of neatness and good workmanship, resort must be made to *scarfing* or to fishing with iron plates, or both. **Scarfing,** which is sometimes called **splicing,** is the cutting and fitting of the ends of two pieces of timber in such a manner that they will enter into and fit each other so as to form a comparatively secure joint, simply from the conditions of their joining surfaces. They are usually made more secure by means of hardwood keys and iron bolts or screws, but the primary consideration should be to make the unsecured joint as strong as possible by properly proportioning its details and parts. This proportion will vary according to the stress to which the beam is likely to be subjected. Fig. 10 shows a form of joint applicable to a timber that will be subjected to compression, as the two abutting surfaces at *a b* and *c d* are equal to the entire cross-section of the timber, and are at right angles to the line of compression. Under tension, however, the pieces will immediately pull apart unless secured by bolts *e*, *e* and plates *f*, *f*, as shown. In this case the entire tensile stress must be borne by the plates and the sections of beam immediately under them and between the bolt holes and the end of the beam, while the bolts will be subjected to a shearing stress.

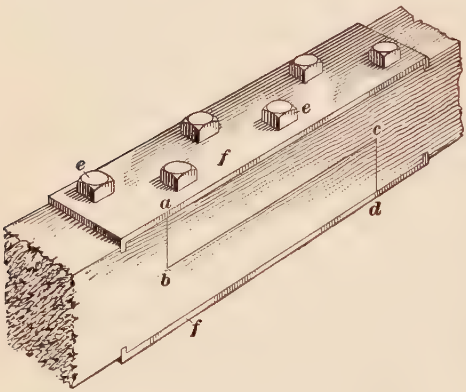


Fig. 10

16. Tabled Scarf.—In Fig. 11 is shown a form of joint, called a **tabled scarf,** similar to that shown in Fig. 10, but more suitable for a timber subjected to tension. The abutting surfaces *a*, *b* and *c*, *d* are cut down to slightly more than half the depth of the timbers to be joined, but at the centre of the joint a table *e f* is

formed which effectually prevents the timbers pulling apart when subjected to tension. The timbers are securely held together by iron straps *g*, *g* secured by the plates *h*, *h* and the nuts *i*, *i*.

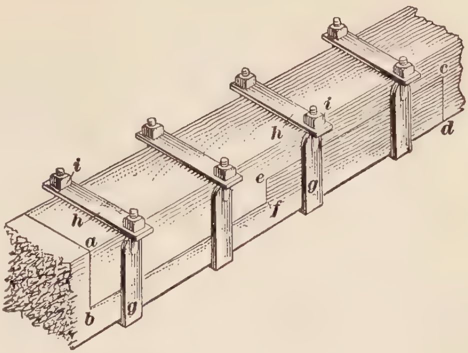


FIG. 11

17. In Fig. 12 is shown a joint that, under compressive stress, is all that is ordinarily required, but if subjected to tension, the entire stress must be borne by the keys *a*, *b*. It is evident that the failing of this joint under a tensile stress will be caused by one or more of the following conditions: The keys *a*, *b* might shear through and permit the two pieces to slide apart; the wood of the beam might split or shear off on some line from *c* to *d e*, allowing the pieces to pull apart without disturbing the keys; or the beam might part under the tension at the thinnest point, as at *f*. The advantage of this joint over that shown in Fig. 10 is that the abutting parts can be better drawn together by means of the keys, while the tongues *d e* and *g h*, at the butt joints, tend to keep the surfaces of the timbers flush, even during shrinkage. Should the two pieces composing the joint shown in Fig. 12 shrink to any considerable extent, the only result would be the loosening of the bolts *i*, *i* holding the straps *j*, *j* in position,

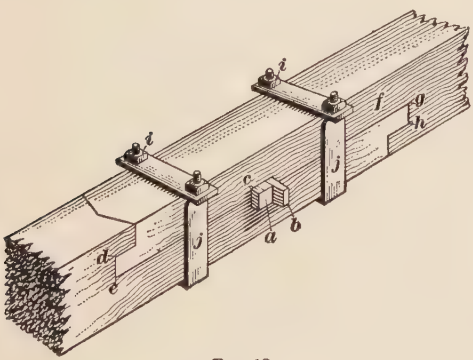


FIG. 12

which could be tightened from time to time, the joints being thus maintained close and secure at all times. This joint is an improvement on that shown in Fig. 11, but the abutting parts shown at *d e*, *g h* are not so effective to resist compression as are the square ends shown in the former figure. Great care should be exercised, when this joint is to be subjected to tensile stress, to see that the keys are well driven, otherwise the joint is liable to work loose. In a joint of this character, the most perfect fitting is required, and when made in a first-class manner it should hold together quite well without the straps.

18. The joint shown in Fig. 13 is designed to resist tension, as in a tie-beam. The line *a b* is carried across the timber in a slanting direction, being offset at *b c*, and *c d* is drawn parallel with *a b*. The shoulders *a e* and *d f* should never be less than one-sixth the depth of the timber and should be at right angles to the slanting lines. This style of joint is not adapted to compression, as the oblique surfaces tend to rupture the joint when so subjected; however, it is used largely for joints under tensile stress. The joint, Fig. 13, is tightened by means of the wedges *i*, *i*, and strengthened by means of the plates *g*, *g* secured with bolts and nuts.

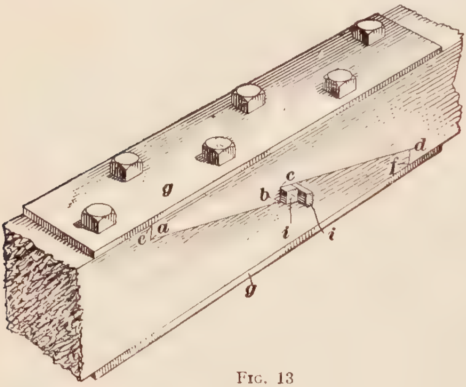


Fig. 13

19. When a beam is subjected to a transverse stress, its top is in compression and its under side is in tension. Therefore, when a beam is under a transverse stress, such as supporting a floor or other similar load, a joint as shown in Fig. 14 should be used.

Fig. 14

The line *a b* runs at right angles to the top of the beam, thus forming a square shoulder, and extends down one-third the depth of the beam. This adapts the upper half to a compressive stress, while the under side is scarfed on the line *b c d*. The length of the scarf may be from about three to four times the depth of the beam. The iron plate placed as shown in the figure takes up the tension on the under side of the beam.

20. Fig. 15 shows a modification of the joint shown in Fig. 13, in that the line *a b* is continuous and passes through the centre of the keyway *g h*, and also in that the meeting line of the two timbers is cut at an obtuse angle *c d e*. This renders the beam much more reliable under a cross-stress, tending to bend it in the direction of its width, and the pointed toe also tends to keep the timbers flush. Like Fig. 13, this joint is better suited to a tensile than to a compressive stress. If used in a position where it will be subjected to a transverse stress, it should have the upper half prepared as described in the preceding article. Parts of the stress are taken by the plates *i*, which are held in place by the bolts *j*. The shoulder *b f* is given a cut similar to *d f* in Fig. 13.

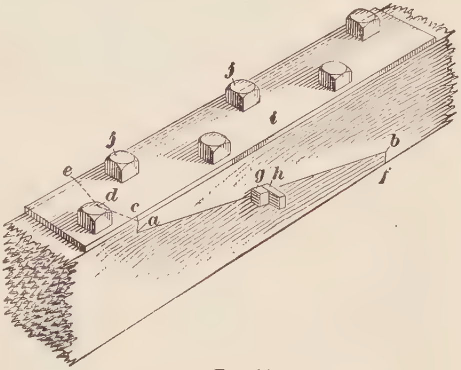


Fig. 15

21. A method of lengthening timber and preserving a considerable degree of strength, both for longitudinal and for transverse stress, is shown in Fig. 16. Three thicknesses *a*, *b*, *c* of timber of the same size are bolted together with four bolts *m*, the

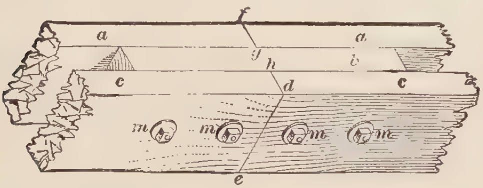


Fig. 16

joints *f g* and *h d e* being squarely sawn and tightly butted in order to secure a good bearing. The bolts must fit the holes exactly, and the nuts on their ends must be screwed as tightly as possible ; where timbers are over 6 inches deep, two bolts in the depth should be used. This joint will separate, either by the *sandwich* part being torn apart, the timber shearing between the bolt holes and the end of the beams, or by the bolts shearing if the other parts have a greater resistance.

22. Proportion of Joints.—In setting out scarf joints, such as shown in Figs. 10 to 15, where bolts and plates or bolts alone are to be used, the whole length of the joint should be twice the depth of the timber, if oak, ash, elm, or hard pine is used ; but if pine or spruce is used, the joint should be from three to four times the depth of the timber. When the timber is thoroughly seasoned, the joints shown in Figs. 12, 13, and 15 will be self-sustaining without bolts and plates, but for the small saving acquired it is not wise to omit them.

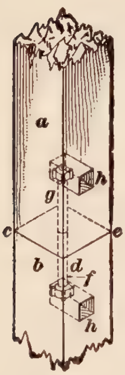


Fig. 17

23. Posts.—In Fig. 17 is shown a form of joint more suitable for a short post than any of the foregoing scarfed joints, but it is unfitted for tensile stress. The ends of the timbers *a* and *b* are carefully squared on the line *c d e* ; in the centre of the end of each piece is bored a hole to take the stud bolt shown dotted at *f g*. A nut for the bolt is inserted in a square hole *h* cut not less than two-thirds the thickness of the post from each end. The nuts are screwed tight on each end of the stud bolt through these holes. This brings both ends of the post into close contact, so that there will not be any perceptible compression at this point when the working load is imposed.

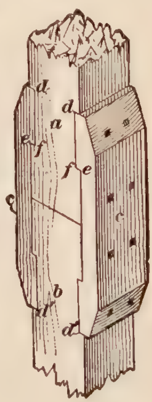


Fig. 18

24. In Fig. 18 is a cheaper form of joint for a similar purpose, though this may also be used in positions

where it will occasionally be subjected to slight tensile stress. It is an improved form of that shown in Fig. 8, having *indents* cut at *d f e* in order that any tensile stress will come on the wooden fish-plates, or battens, *c*, and the lugs of the timbers, and not entirely on the nails, or spikes, as is the case in Fig. 8.

25. In Fig. 19, the fish-plates are replaced by iron straps *c* not less in breadth than one-sixth the thickness of the timber. These straps are sunk into the face of the wood a depth equal to their thickness, as shown at *e*. Holes are bored or punched into these straps to receive the lagscrews, or spikes, which serve to bind the timbers and straps together. The iron or hardwood dowel *d* in the centre of the post serves to keep the two pieces in alinement. It is always better, whenever possible, to have a post in one piece than to resort to any of the joints shown in Figs. 17 to 19.

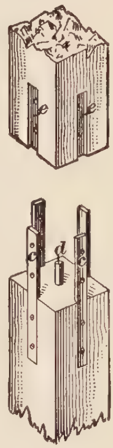


FIG. 19

26. Halved Joints.—When timbers cannot be obtained of sufficient length to form an entire sill, plate, or other horizontal member, or when timbers cross one another and have to be flush on both upper and lower faces, it is necessary to resort to some form of a **halved joint,** as shown in Figs. 20 and 21. Fig. 20 shows an ordinary halved joint obtained by cutting away one-half of the thickness and width of each timber *e*, *d*, and then fitting the remaining half of each piece into the space formerly occupied by the half cut away, as indicated by the dotted lines. The piece *d* is shown at right angles to the piece *e*, which would be its position in the corner of a building, as shown at *m*, Fig. 25. By turning the piece *d* so that its end *f g i h* will coincide with the end *o p q n* of the piece *e*, the joint will connect the two pieces in a continuous line, and the shoulder *j* will coincide with the end *m l k r*, as shown in Fig. 21; but when such a condition exists, *bevelled halving*, which is sometimes called *bevelled* or *oblique splicing*, is considered preferable. This form of joint is effected by cutting away a little more than half the thickness of the timber at *a b d c* and *l m*, Fig. 21, and leaving a little more than half the thickness

at the ends $f\,g$ and $j\,k$. The formation of this joint requires great care, lest the timbers are weakened by cutting too deeply

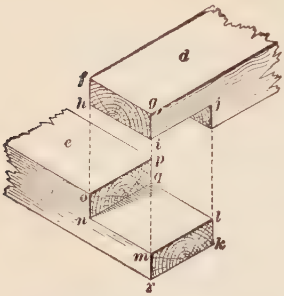


Fig. 20

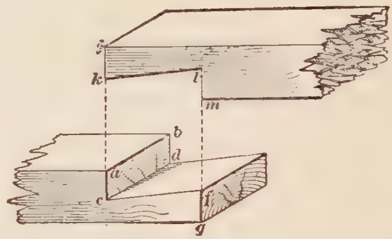


Fig. 21

at $a\,c$ and $l\,m$, but, when properly made, this joint does not pull apart so easily as the plain joint.

27. Dovetailed Halving.—A form of joint used where prevention from sliding is desired is known as **dovetailed halving.** Fig. 22 shows two forms of this joint: The timber m is first halved on the end in the same manner as the timber d, Fig. 20; the

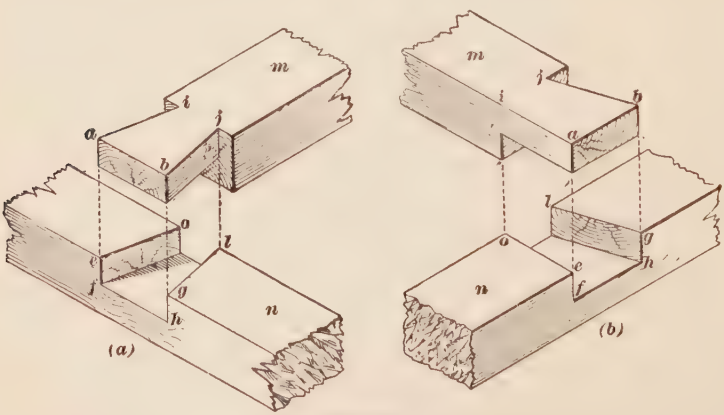


Fig. 22

remaining half thickness is then cut to the wedge shape $a\,b\,j\,i$, which is called a **dovetail.** A *dovetail mortise* $e\,f\,h\,g\,l\,o$ is then cut in the timber n half the thickness of the timber m, and the two pieces are driven together and held in place with spikes or

screws. The form shown in (*a*) is best adapted to positions where timber *m* is intended to be placed at right angles to the timber *n*. Although the form shown in (*b*) is also used in similar positions, it is best adapted to positions where the timber *m* makes an acute or an obtuse angle with the timber *n*, as is shown in Fig. 25, where the timber *n* forms, at the same time, a tie and a brace to the two timbers *h* forming the plate.

JOINTS FOR BEARING

28. Mortise-and-Tenon Joints.—Where greater strength and security than can be obtained from the butt joint are required, a **mortise-and-tenon joint,** as shown in Fig. 23, is used. A rectangular hole *a b c d*, called a *mortise*, is cut into one of the timbers *w* and a projecting pin, or *tenon*, *e f g*, which fits into and exactly fills the mortise, is formed on the end of the other timber *y*. The *shoulders* of the tenon are shown at *h i k* and *l j*. The width *d a* of the mortise is one-third the thickness of the timber in which it is cut, and the mortise is cut into the centre of the thickness; but if one timber is larger than the other, they are usually so framed that, when brought together, one face of each piece will be flush.

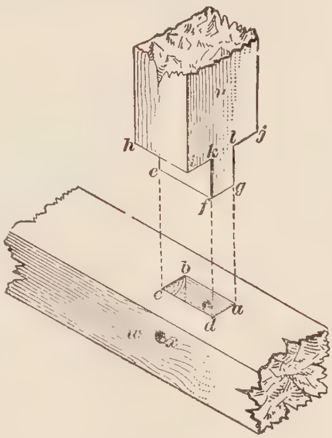


FIG. 23

29. Method of Securing Mortise-and-Tenon Joints.—Mortise-and-tenon joints are nearly always secured in place by means of what is called a *treenail pin*, which is inserted in the following manner: After the mortise is cut and the tenon is accurately fitted to it, a hole is bored in the timber squarely through both cheeks of the mortise, as shown at *x*, Fig. 23. The position of the hole *x* is accurately marked on the tenon *e f g*, and a hole is then bored through the tenon *but drilled from* $\frac{1}{16}$ *to* $\frac{1}{8}$ *inch*

nearer the shoulder than the marks made through the hole in the mortise. When the tenon is inserted in the mortise, the relative position of the holes will be somewhat as shown in Fig. 25 (*a*), which is an enlarged section through the intertie and corner post on the line *x y*. A wooden pin is then driven through these holes, and, by forcing them into line, the shoulders of the tenon *p* are brought tight up against the cheeks of the mortise *q*, thus making the joint firm and secure, as well as free from any liability to work itself loose.

This wooden pin should be cut from a piece of straight-grained, tough, and durable wood, preferably teak or oak, about 1 to $1\frac{1}{2}$ inches square on the ends, and about 2 inches more in length than the mortised timber is in thickness. The corners are planed off, bringing the pin down to an octagonal shape on the ends, and its sides are slightly tapered about one-fourth the length, so that it will enter the holes bored through the cheeks of the mortise and the pin of the tenon. If, through carelessness or error in measurement, the hole in the tenon is not slightly nearer the shoulder than the hole in the mortise, the joint will not be tight, and may result in what is called a *push bore*, which is a term given to this joint when the driving of the pin loosens the pieces instead of tightening them.

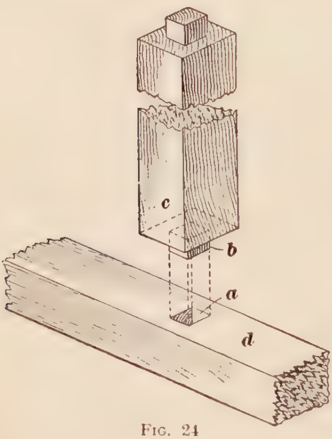


FIG. 24

30. Stump, or Stub, Tenon. Another form of tenon is the **stump** or **stub tenon** shown in Fig. 24, where the timber *c* has a stub tenon *b* worked upon it, while *d* is the timber with the mortise *a* worked in it to receive the tenon. The tenon is much shorter than in the previous example, being usually only about 1 to $1\frac{1}{2}$ inches long, and is not pinned. The application of this form is shown in Fig. 33, in the detailed views of the joints *C* and *D*.

31. The Mortise and Tenon With Wedges.—The joint shown

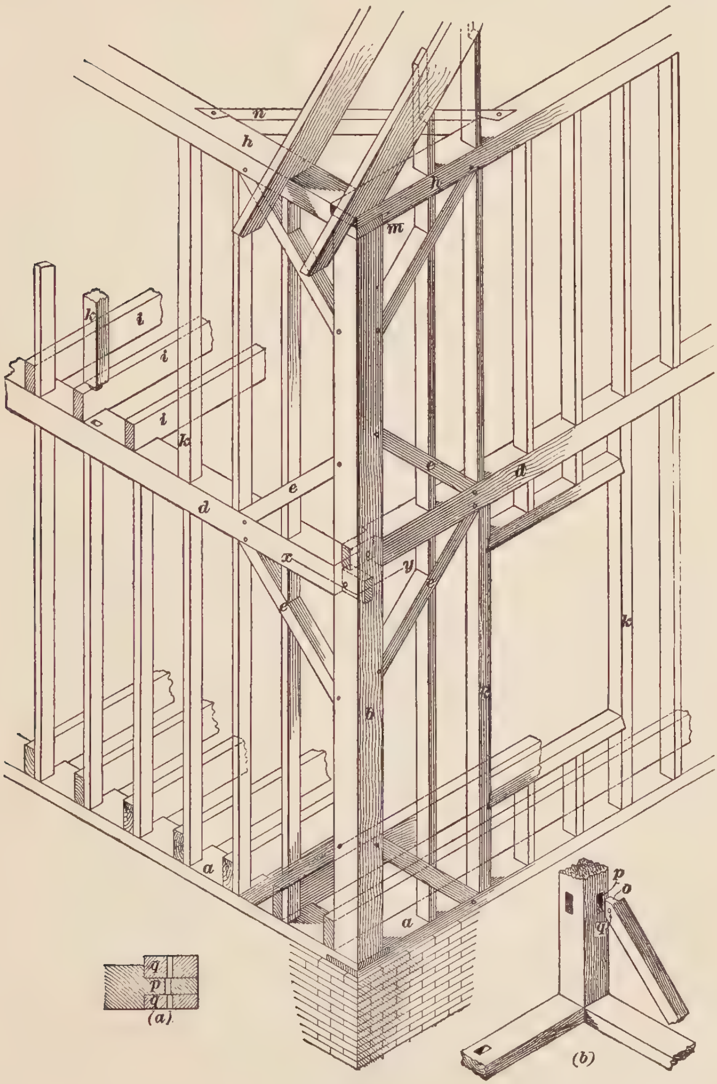


Fig. 25

in Fig. 26 is similar to that shown in Fig. 23, except that the

mortise, which is wedge-shaped, is cut through the timber, and instead of pins being inserted to secure the joint, wedges *a*, *a* are driven into the spaces between the ends of the tenon and the mortise.

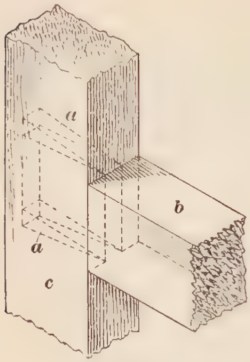


FIG. 26

32. Foxtail Wedging Joint.—In the **foxtail wedging joint**, shown in Fig. 27, the wedges are concealed by the framing, for the mortise is not cut through the timber. This joint is useful where it is desired to conceal the ends of the tenon or wedges, or where it would be impossible to drive the wedges in at the back of the timber. It is formed by inserting wedges *a*, *a* in notches in the tenon that is cut in the timber *b* before it is placed in the mortise cut in the timber *c*. Then, as the tenon is driven into the mortise, the

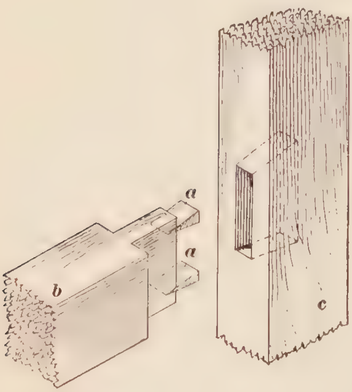


FIG. 27

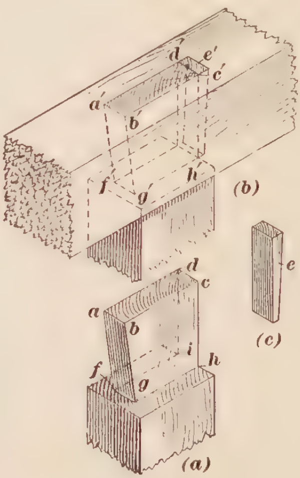


FIG. 28

wedges strike the back of the mortise and, splitting the tenon, cause it to fill the wedge-shaped space.

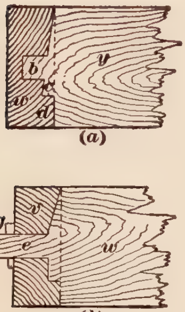
33. Dovetail Tenon.—The joint, Fig. 28 (*a*) and (*b*), known as a **dovetail tenon**, is similar to that shown in Fig. 26, with the

exception that only one wedge is used to secure the tenon. The tenon, shown in (*a*), is made of dovetail shape, that is, the distance across the tenon is wider at *a d c b* than it is at *f i h g*. The mortise in the timber shown in (*b*) is made sufficiently wide to take the end of the tenon *a b c d* which is inserted in it, so that the splayed face *a b g f* of the tenon fits accurately against the splayed cut a' b' g' f' of the mortise, then the wedge *e*, Fig. 28 (*c*), is driven into place against d' c' h' as shown at e', Fig. 28 (*b*), and the joint is made tight.

34. Uses of Mortise-and-Tenon Joints.—The mortise-and-tenon joint is, in some form or other, in constant use in carpentry. In roofs, floors, trussed partitions, and braced-frame structures, it forms the joint of nearly every two important timbers that come in contact. In Fig. 25 is shown the corner of a braced-frame building, where *b* is the corner post mortised into the sill *a* at the bottom, and into the plate *h* at the top. The interties *d*, on one of which the second tier of floor joists *i* rests, are mortised into the corner post and secured with a pin as already described, while the angle braces *e* are mortised into both the intertie and the corner post. The tenons on these braces are cut somewhat differently from those on the other members, owing to the diagonal position of the timbers. In (*b*) is shown an inside view of the corner post and the joints between it and the lower braces. The top of the brace tenon *o* is cut so as to enter the corner-post mortise *p* at right angles to the face of the post; while the bottom of the tenon is in the direction of the plane of the under side of the brace, and the lower side of the mortise is cut on the same plane. The hole for the pin in the tenon is shown at *q*, but does not show on the inside of the corner post, as it is unnecessary to bore the hole all the way through. This constitutes the system of braced-frame construction so much used in America and in the Colonies, but seldom seen in the British Isles. Though the studs are sometimes mortised into both sill and intertie, or into intertie and plate, they are thus joined simply to hold them in their places and not to add strength to the general frame. Studs adjacent to openings are usually 4 inches in thickness, as shown at *k*, and should always be mortised for good work, but

generally they are formed with two thicknesses of the regular stud, and butt-jointed and toe-nailed to plate and intertie. The intermediate studs are simply spaced 16 inches on centres and butt-jointed to form the ribwork between the posts.

35. Tusk Tenons.—Mortise-and-tenon joints are sometimes used for the framing of the timbers round staircase wells, chimney breasts, and other openings, as shown in Fig. 44. Here the joists *a* are only mortised into the trimmer *e*, which in turn is supported at one end by the stirrup *h* instead of being mortised, as at the end *g*. A similar style of tenon, called a **tusk tenon,** is shown at *b*, in Fig. 29 (*a*), where the tenon *b* on the joist *y* is let into the trimmer *w* at its centre. To secure additional strength, a tusk *c* is cut on the joist, to rest on a shoulder *d* formed on the trimmer. The length of the tusk and the thickness of the tenon should each be about one-sixth the depth of the beam. In (*b*) the tenon *e* extends through the beam *v*, and is held securely in place by a wooden pin, or wedge *g*. This is the form of mortise sometimes used to secure the trimmer to the trimming joist, while the form shown in (*a*) is sometimes used to secure the floor joists to the trimmer. Where the joints are made with patent beam hangers or stirrup-irons, no mortising is necessary. In America, a trimmed joist is known as a *tail beam*; a trimmer, as a *header*; and a *trimming joist*, as a *trimmer*. In Scotland, trimmers and trimming joists are known as *bridles* and *bridle joists*, respectively.



(*a*) (*b*)

Fig. 29

36. Stirrup Irons.—**Stirrup irons,** or **hangers,** are often used instead of making the tusk-tenon joint. They usually consist of pieces of wrought iron $2\frac{1}{2}$ inches by $\frac{3}{8}$ inch, bent to form a hook over the trimming joist, and a seat in which the trimmer can rest, as shown at *h*, Fig. 44. The trimming joist and trimmer are usually nailed together to keep the joint close, while the stirrup iron carries the weight; for good work, however, a strap or bolt should be used to keep the trimming joist and trimmer in close contact. The use of joist and beam hangers, etc., simplifies greatly the

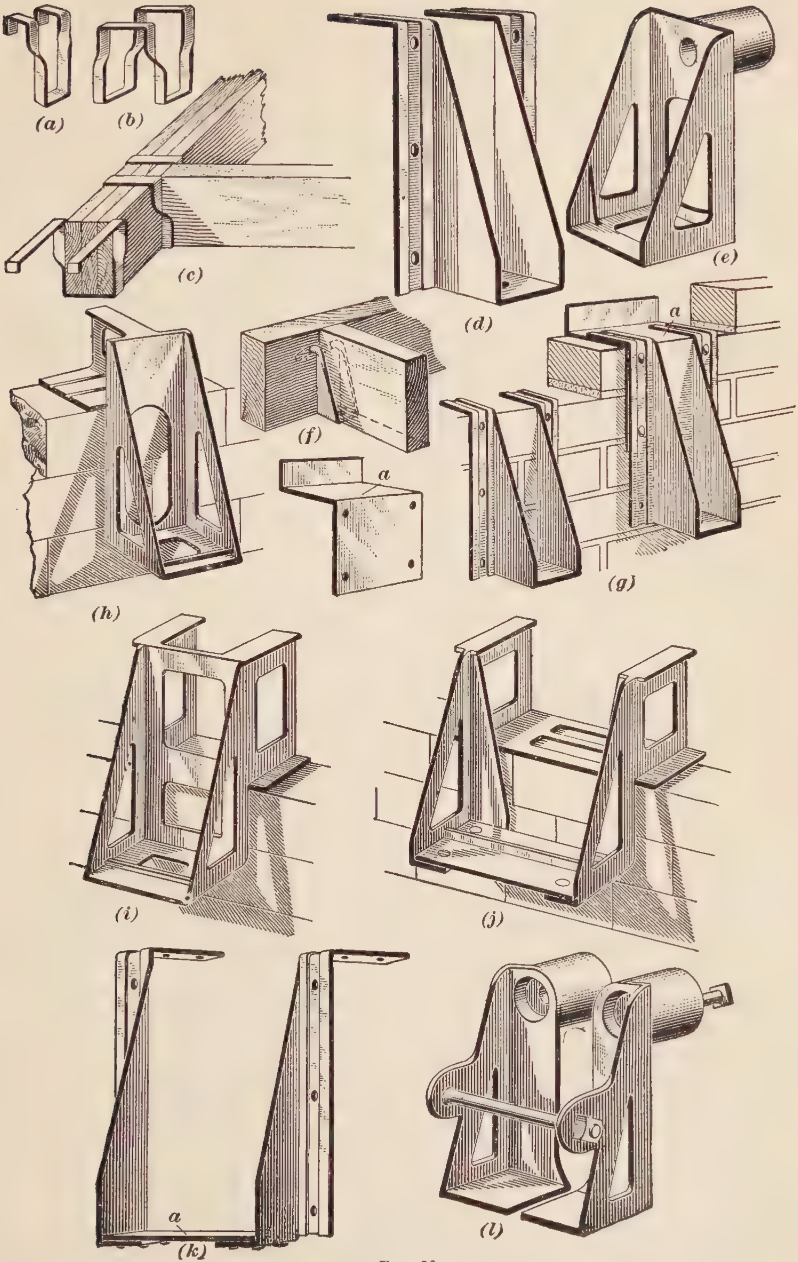
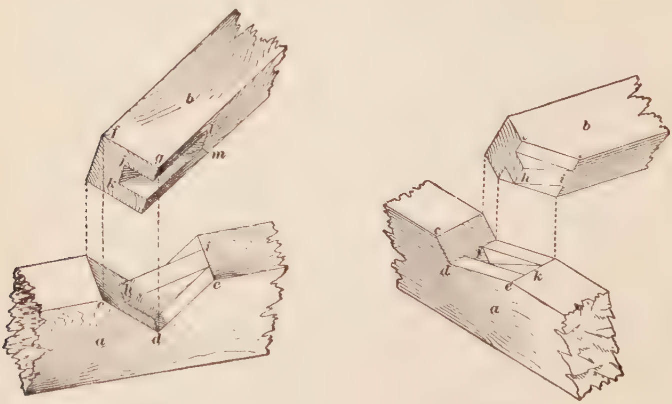


Fig. 30

work of framing. In Fig. 30 are shown various styles made to meet different conditions. With these hangers, a good bearing and firm support for the joists, beams, etc., may be had, and in case of fire the timbers may give way without injuring the walls. In (*a*), (*b*), and (*c*) are shown different forms of wrought-iron stirrups, (*a*) and (*c*) being made to carry trimmers, while (*b*) is made double, so as to carry a beam on each side of a main girder. In (*d*), (*e*), and (*f*) are shown joist hangers for junctions of wooden trimmers and trimming joists, and in (*g*), (*h*), (*i*), and (*j*), hangers for the support of beams at brick walls where it is undesirable to allow the beams to pass into the walls. At *a*, in (*g*), is shown the wall-bearing plate to which the stirrup is riveted. In (*k*) is shown a hanger for heavy girders or joists, adjustable to suit several sizes of timber by changing the bearing plate *a*, thus serving the same purpose as that shown in (*l*), which shows a hanger made in right and left parts and fastened together by a rod and bolt.

OBLIQUE JOINTS

37. Bridle Joints.—A bridle joint, Fig. 31 (*a*), is used when a secure footing is required for the foot of a rafter or strut. The



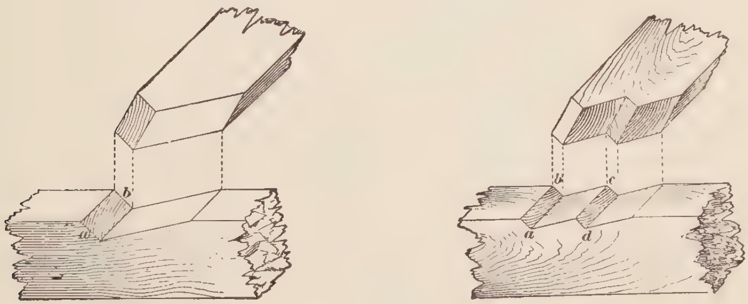
(*a*) (*b*)

FIG. 31

tie-beam *a* is notched on top to receive the foot of the rafter *b*; the side *d e* of the notch is in the direction of and at the same

angle as the slant of the rafter; while the side *d c* is at right angles to *d e*, and equal in length to the depth of the rafter at *f g*. The *tenon h i* is left standing when the notch *c d e* is cut, and a mortise *j k m l* is cut into the end of the rafter to slip over or straddle this tenon, and thus prevent the rafter from slipping. Another method of treating this joint is to work the tenon *h i*, Fig. 31 (*b*), on the rafter *b*, and sink the mortise *j k* into the tie-beam *a*. The tie-beam *a* is then notched on the line *c d* a distance equal to only half the depth of the rafter *b*, but is still kept at right angles to the direction of the slant of the rafter, while the line *d e* has a pitch that varies in different cases, according to circumstances.

38. Footing Rafters Without Mortise and Tenon.—A method of footing the rafters on tie-beams without the mortise and tenon is shown in Fig. 32 (*a*), where the joint is similar in every respect to those in Fig. 31, except that the mortise and the tenon are omitted. Fig. 32 (*b*) shows a variation that is used when the



(*a*) (*b*)

Fig. 32

notching of the tie equal to one-third or one-half the depth of the rafter will weaken the beam too much. Two notches are made, each of which should be equal to from one-sixth to one-quarter the depth of the rafter, so that the sum of the two bearing surfaces *a b* and *d c* is equal to the single bearing surface *a b* in (*a*).

39. This completes the description of the joints most commonly used in the framing of buildings. In Fig. 33 is shown a queenpost truss, with perspective details of the various

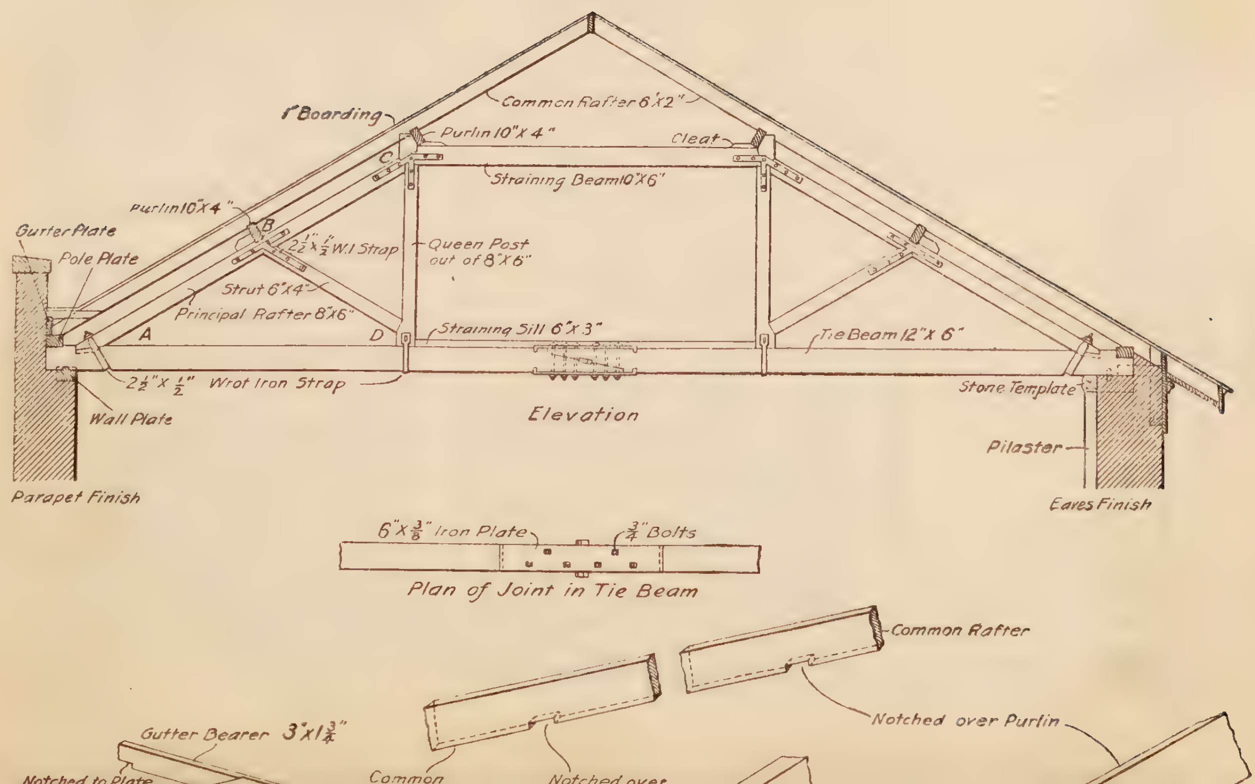
joints suitable for a span of from 40 to 45 feet, in which a number of the joints described herein are shown. At one end of the truss is shown the proper construction in case a parapet wall is used; at the other end is shown the common eaves construction.

FLOORS

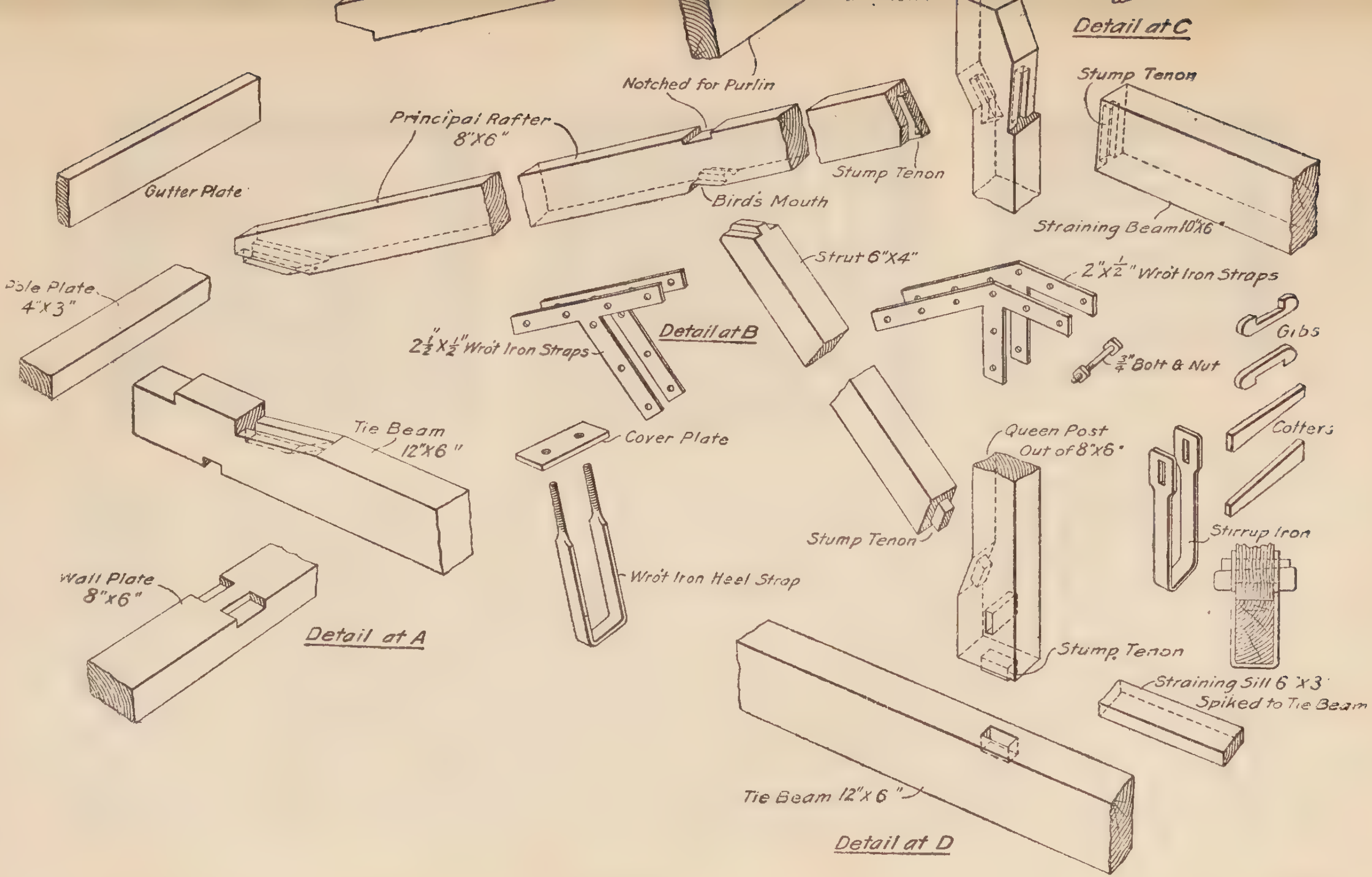
CONSTRUCTION AND FINISHINGS

40. Wooden floors are composed of floor boards supported by joists, and in addition to the floor load they must usually carry a ceiling of plaster, wood, or metal, the weight of which must be considered. In the construction of floors, the work of the carpenter has, to a considerable extent, been reduced by the introduction of many fire-resisting materials, for steel joists and concrete now take the place of the timber formerly used, although, in many cases, chiefly dwelling houses, floors are still constructed with wooden joists. These joists may span in one length the space between the bearing walls, or they may have intermediate supports in the form of wooden or steel beams. When constructed entirely of wood, floors are classified as follows: *single-joisted floors, double-joisted floors* and *framed floors.*

In the **single-joisted floor,** the joists *a*, Fig. 34 (*a*), sometimes termed *bridging joists*, span in one the space between the bearing walls *b, b,* their ends resting on a wall plate *c c* ; *d* is the herring-bone strutting described later. In the **double-joisted floor,** Fig. 34 (*b*), the joists *a* rest on wooden beams *b*, called *binders*, which are supported at the ends by the bearing walls, *c, c* ; *d, d* are the templates on which the binders rest, and *f*, the floor boards. In the **framed floor**, Fig. 34 (*c*), usually adopted for larger spans, the joists *a*, as in the case of the double-joisted floor, rest on binders *b*, which are framed into wood girders *c* supported at the ends by the walls *d, d* and resting on templates *e, e*. The floor boards are shown at *f*.



1" Boarding
Common Rafter 6"X2"
Purlin 10"X 4"
Cleat
Straining Beam 10"X6"
Purlin 10"X 4"
Gutter Plate
Pole Plate
B
C
$2\frac{1}{2}$" X $\frac{1}{2}$" W.I Strap
Queen Post out of 8"X6"
Strut 6"X4"
Principal Rafter 8"X6"
A
D
Straining Sill 6"X 3"
Tie Beam 12"X 6"
$2\frac{1}{2}$"X $\frac{1}{2}$" Wrot Iron Strap
Stone Template
Wall Plate
Elevation
Pilaster
Parapet Finish
Eaves Finish
6"X $\frac{3}{8}$" Iron Plate
$\frac{3}{4}$" Bolts
Plan of Joint in Tie Beam
Common Rafter
Notched over Purlin
Gutter Bearer 3"x$1\frac{3}{4}$"
Notched to Plate
Common
Notched over



Detail at C
Stump Tenon
Straining Beam 10"X6"
Notched for Purlin
Principal Rafter 8"X6"
Stump Tenon
Bird's Mouth
Gutter Plate
Pole Plate 4"X3"
Strut 6"X4"
2"X$\frac{1}{2}$" Wrot Iron Straps
Gibs
$\frac{3}{4}$" Bolt & Nut
Cotters
Detail at B
$2\frac{1}{2}$"X$\frac{1}{2}$" Wrot Iron Straps
Tie Beam 12"X6"
Cover Plate
Queen Post Out of 8"X6"
Stump Tenon
Stirrup Iron
Wrot Iron Heel Strap
Wall Plate 8"x6"
Detail at A
Stump Tenon
Straining Sill 6"X3" Spiked to Tie Beam
Tie Beam 12"x 6"
Detail at D

FIG. 33

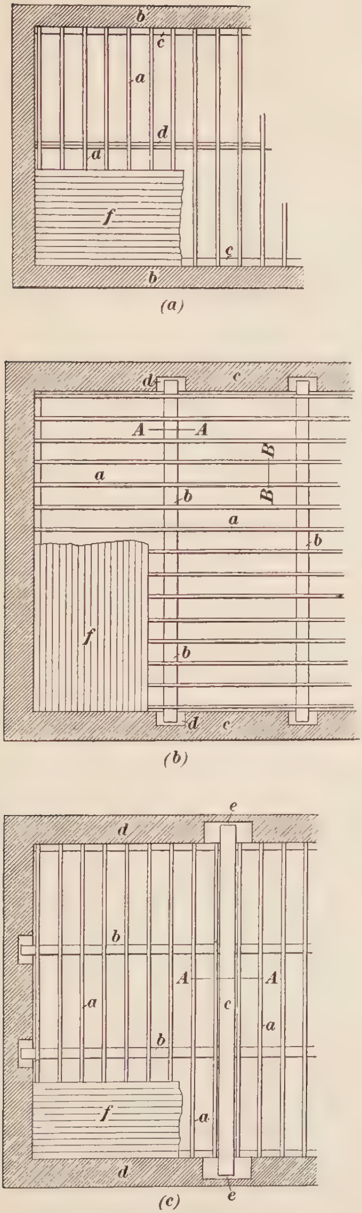


FIG. 34

41. The Single-Joisted Floor. The joists, or bridging joists, of a single-joisted floor are usually spaced from 14 to 18 inches from centre to centre. The scantlings vary according to the load to be carried. The joists are *sized* or notched on the plate, as shown in Fig. 35, in order to bring their tops to an even line, any variation in the depth of the joists *b* being removed with the notch at *e d*, so that all the joists are exactly the same depth from *d* to *c*, thus securing an alinement of their upper edges. Nearly all timbers will curl or warp more or less in drying out, or seasoning, and when the joists are laid they should be placed with the convex, or *crowning*, side upwards, in order that any deflection of the joist due to the superimposed weight will bring the floor to a level line rather than produce a sag or dip in the middle of its span. Where spans are over 16 feet, the upper edges of the joists should be *cambered*, or rounded, at the rate of $\frac{3}{4}$ inch in 20 feet, to allow for ultimate settlement.

42. There are various rules for determining the section of joists required, but a very simple method is to divide the span,

in feet, by 2 and add 2. Thus, for a span of 16 feet, the depth of the joist will be $16 \div 2 = 8$; and $8 + 2 = 10$ inches. In

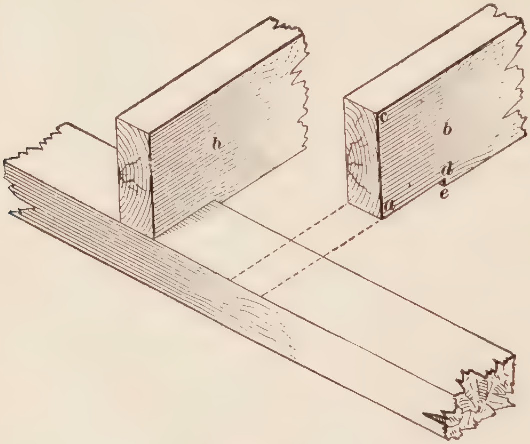


FIG. 35

practice, however, it is the custom to adhere to stock sections supplied by the timber merchants. These can be obtained from about 3 inches by 2 inches up to 11 inches by 3 inches.

The following are the most common sizes in use:

For spans from 6 to 8 feet, $6'' \times 2''$ or $6\frac{1}{2}'' \times 2\frac{1}{2}''$
For spans from 8 to 10 feet, about $7'' \times 3''$
For spans from 10 to 15 feet, $8'' \times 3''$ to $9'' \times 3''$
For spans from 15 to 18 feet, about $11'' \times 3''$

However, in some parts of the British Isles, a few of the intermediate sizes are frequently used. The $6\frac{1}{2}'' \times 2\frac{1}{2}''$ joist is a very common size in Scotland. The section to be used will also depend on the kind of timber and the country from which it is imported.

The ends of the upper floor joists rest on stone templates, or wooden wall plates, but the former are preferred in the case of external walls. On internal brick partitions, wall plates are most commonly used. In brick or stone walls the joists are maintained at the same level by placing small pieces of slate under the narrow ones, and thus raising them to the proper level. Thin slips of wood are sometimes used instead of slate, but as

they are seldom made of a uniform thickness and squeeze readily under pressure, they are not to be recommended.

43. In building in the ends of the joists in the external walls, care should be taken to preserve an air space round the joist and thus lessen the liability to dry rot, the end wood of the joist or the whole of the portion of the joist built in the wall might be tarred as a further preventive. All joists should be kept

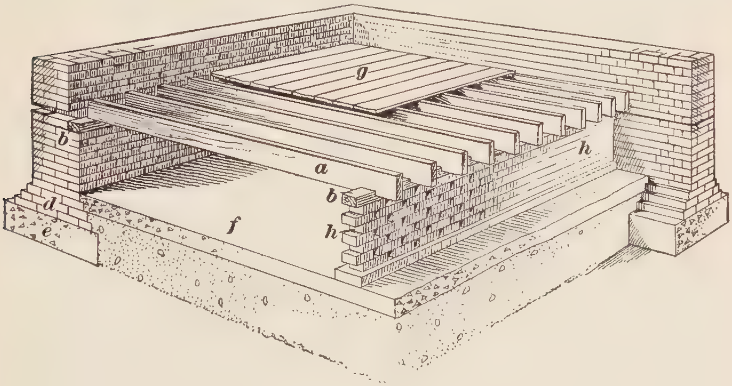


Fig. 36

from 2 to 4 inches away from a wall containing smoke flues, and, when built in, should not be nearer a flue than 9 inches, unless protected by a fireclay shoe. If a number of flues occur together in a wall supporting joists, the joists opposite the flues should be trimmed or rest on a stone or brick corbel course or hung by iron stirrups, see Fig. 30.

44. Ground Floors.—**Ground floors,** when no basement or cellar occurs underneath them, are usually built with joists *a* from about 6 inches by 2 inches to 7 inches by 3 inches, supported on dwarf or sleeper walls *h* in spans from 6 to 8 feet, as shown in Fig. 36. The joists may rest on wall plates *b* or stone templates, the latter being preferred.

The whole area under the wooden floors should be laid with concrete *f*, or with broken stones covered with asphalt, to prevent dampness and dry rot. This damp-proof course should

be continued through the thickness of the external walls just above the ground line. The space under the ground floor should also be well ventilated. At *b* is shown the brick wall with its footings at *d* resting on the concrete *e*, while at *g* are shown the floor boards.

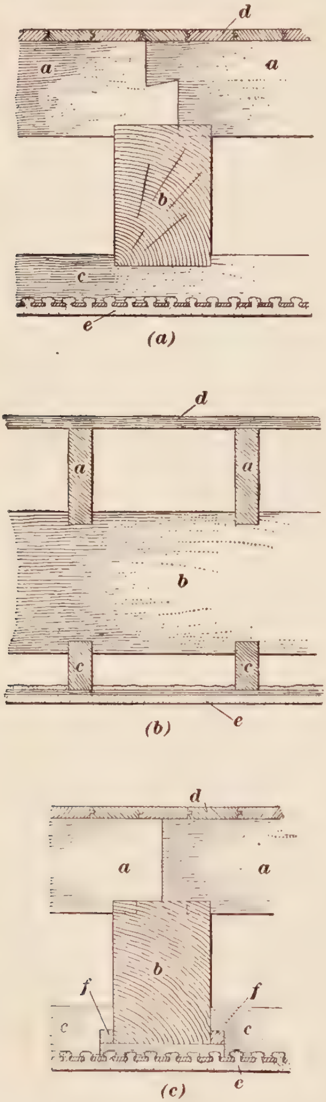


FIG. 37

45. Double Floors.—A part plan showing a **double-joisted floor** is shown in Fig. 34 (*b*). This form is useful where the openings are wide and in buildings to be subjected to heavy loads. The building may be spanned with large wooden beams resting on the walls or on solid piers and carrying the floor joists, which will then run parallel with the walls. In Fig. 37 (*a*) is shown a section through the line *A A* in Fig. 34 (*b*), where *b* is the binder, *a* the floor joists, and *c* the ceiling joists underneath. In (*b*) is shown a section through the line *B B* in Fig. 34 (*b*), where *b* is the binder, *a*, *a* the floor joists, and *c*, *c* the ceiling joists. In each case, *d* shows the floor boards and *e* the lath and plaster ceiling. The common or bridging joists *a*, Fig. 37 (*a*), are cogged on to the binders *b*, which, as in the case of the ordinary joisting in the single floors, should rest on stone templates built into the bearing

walls. A common span for the bridging joists, when wooden binders are used, is about 7 feet, the bridging joists being about 6 inches by 2 inches or 7 inches by $2\frac{1}{2}$ inches. The ceiling joists *c* are notched and nailed to the binders where the ceiling is hung down. Instead of notching, they will sometimes be fixed to fillets *f* nailed to the sides of the binders, as in Fig. 37 (*c*).

46. Instead of wooden binders, steel joists are often used, as shown in Fig. 38. In (*a*) is shown a method of construction where the joist is concealed in the thickness of the floor; *a* is the steel joist; *b*, the floor or bridging joists resting on the bottom flange of the steel joist; *c* is the floor boards; and *d*, the ceiling hung up to battens *e* which are fixed on the under side of the floor joists. At *f* in (*a*) and *g* in (*c*) is shown a batten strip nailed across the joists *b*, *b* to take the floor boards where they occur over the iron joist *a*. In (*b*) and (*c*) are shown two methods of construction when the joist projects below the ceiling. In (*b*), the floor joists *b* are allowed to rest on the wooden plates *f*, *f*, which rest on the lower flange of the steel joist *a* and are bolted through from one side to the other by the insertion, at intervals, of the bolts *g*. In (*c*), similar construction is shown, only the floor joists rest on the angle irons *f*, *f*, and batten strips *e*, *e* are nailed to the sides of the joists *b*, *b* to take the laths on which the plastering forming the beam casing is placed.

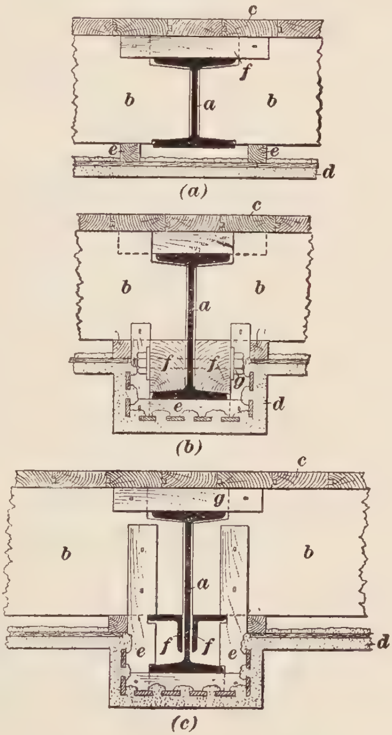


FIG. 38

47. The Framed Floor.—The part plan of a framed floor is shown in Fig. 34 (*c*). In construction, it is similar to the double floor, except that the binders, instead of resting on the bearing walls, are supported by girders. At one time it was the practice to make these of wood, now, however, steel is nearly always used. In Fig. 39, (*a*) is a section on the line *A A*, Fig. 34 (*c*), showing the wooden binders *b* tusk tenoned into the wooden girder *c*. The floor joists *a* support the floor boards *f*, and the ceiling joists *e* support the plaster ceiling *d*. In Fig. 39 (*b*) is shown a section similar to that shown in (*a*), but instead of the ceiling being flat and kept at the level of the under side of the girders, it is kept at the under side of the floor joists. Panels are thus formed in the ceiling by the binders and girders. The binders *b* are tusk tenoned into the wooden girder *c*, and the floor joists *a* support the ceiling *d* underneath them. Instead of the mortise and tenon being used, the binder might be supported by iron stirrups, as shown in Fig. 30. In Fig. 39 (*c*) is shown a detail of the construction of a floor with steel binders and girders. The binder *b* rests on the bottom flange of the girder *d*, a cast-iron blocking-up piece being placed between the flange of the girder

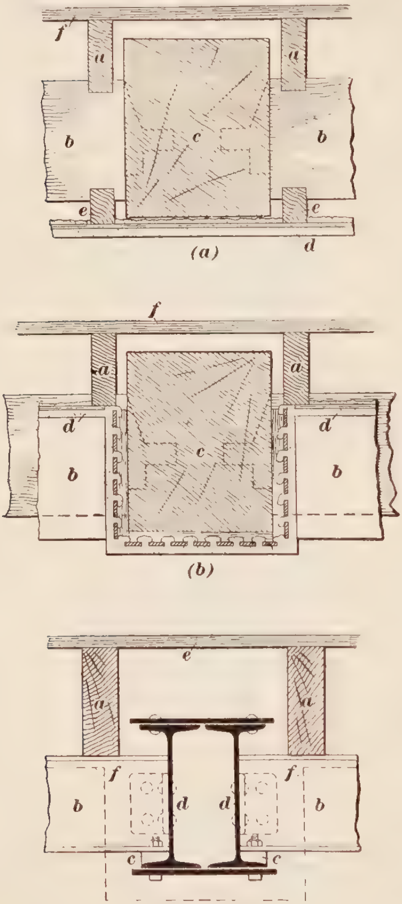


FIG. 39

and the under side of the flange of the binder. The steel binder may be connected to the girder by being bolted through the blocking-up piece *c* to the bottom flange, or it might be connected to the web by means of a steel angle, as shown by dotted lines. At *a* are shown the floor joists resting on top of the steel binders, and at *e* are shown the floor boards. The probable finished line of the ceiling is shown by the dotted lines *f*, *f*.

48. Loads on Floors.—The weight which floors should be calculated to carry varies considerably with the class of structure that is being dealt with, but for ordinary practice it would be quite safe to allow the weights given in Table I.

TABLE I

SUPERIMPOSED LOADS ON FLOORS

Type of Building	Superimposed Loads Per Square Foot Pounds
Dwelling houses, offices, and hotels . .	70
Schools	100
Churches and theatres	120
Ballrooms and drill-halls	130
Workshops, factories, and warehouses	100 to 200 and upwards

In the case of workshops, factories, and warehouses the character

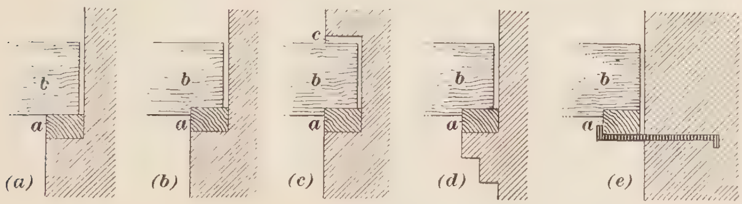


FIG. 40

of the trade and the materials used or stored must be carefully considered in estimating the floor loads to be allowed. To

the superimposed loads given in Table I, of course, it will be necessary to add the weight of the floor itself.

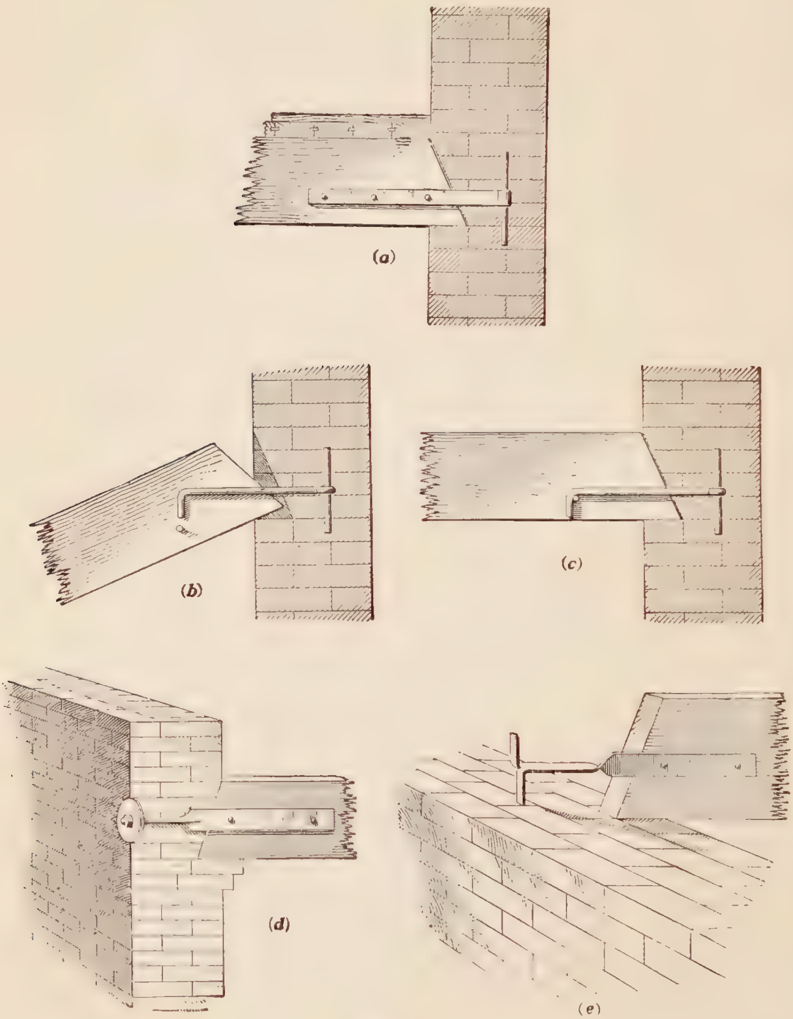


FIG. 41

49. Wall Plates.—When bearing on a wall, the end of a joist is usually allowed to rest on a wooden wall plate. In Fig. 40

several methods of fixing wall plates are shown. In (*a*) a plate *a* is placed on an offset in a wall with the joist *b* resting on it. In (*b*), a similar plate *a* is shown with the joist *b* notched over it. In (*c*) a wall plate *a* built in, with air space *c* all round the joist *b*. While in (*d*) the wall plate *a* and joist *b* are carried on a corbel course. Special iron brackets built into the wall are often used for the purpose of supporting wall plates; these are inserted at intervals of $2\frac{1}{2}$ feet, so that the wall plate is to a great extent kept free from the wall, as shown in (*e*), where *a* is the wall plate and *b* is the joist.

50. Anchors.—In America and some of the Colonies wall plates are not used, but the joists are fastened to the wall by means of iron **anchors.** In Fig. 41 are shown various types of anchors for tying wooden floor joists to brick or stone walls. At (*a*) is shown the usual form which is made with a strap from 20 to 24 inches long, forged over a $\frac{5}{8}$- or $\frac{3}{4}$-inch rod, to form the lug; the strap is spiked to the joists. In (*b*) and (*c*) are shown a rod anchor that hooks over a round rod driven into the joists, and allows the joists to fall out readily during a fire, without dislodging or overturning the brickwork. In (*d*) is shown a strap anchor passing through the wall and threaded for a nut; the washer on the outside furnishes a large bearing area. The brickwork in this case is corbelled out two courses, forming a bearing for the joists, which need not pass more than 2 or 3 inches into the wall. In (*e*) is shown a strap anchor with a twisted end that is split to form a double lug.

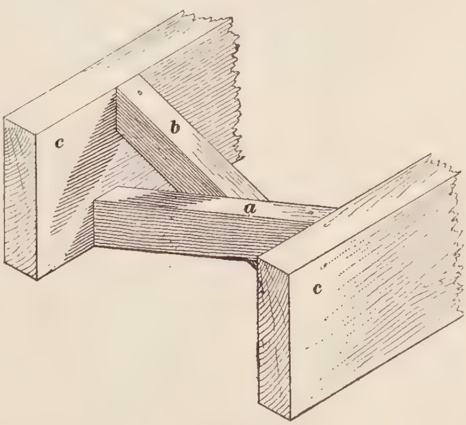


FIG. 42

51. Strutting.—The term **strutting** is given to a system of bracing applied between joists, in order to prevent them from

bending sidewise or curling out of position after they are in place. Bridging also tends to strengthen the floor system, when it is not uniformly loaded, by distributing the weight among the adjacent joists. Fig. 42 shows a simple and effective method by which this is accomplished, called **herring-bone strutting.** Herring-bone strutting is generally formed of $2\frac{1}{2}'' \times 1\frac{1}{2}''$ pieces *a* and *b*, cut between and well nailed to the joists *c*, as shown, and spaced in rows from 5 to 6 feet apart. Strutting is also accomplished by driving in pieces of the joisting between the joists and nailing them well. If care is taken in the cutting, so that the ends butt squarely on to the joists, this is a very effective method and much cheaper than the other. In the case of floors to carry heavy loads, iron tension rods *a*, Fig. 43, are sometimes passed through the joists at right angles to them and alongside the struts *b*. By screwing up the nuts at the ends of these rods, the struts are compressed, and the floor considerably strengthened.

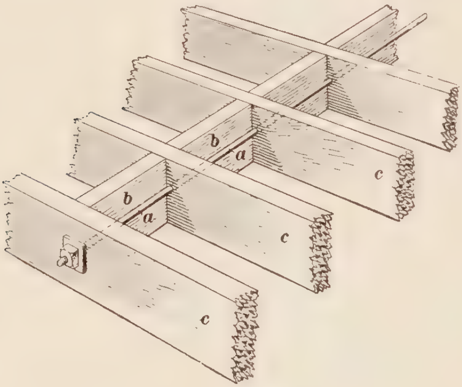


FIG. 43

52. Trimming Joists.—Where a chimney breast occurs in the wall of a building as shown at *c*, Fig 44, it is necessary to frame the joists in such a manner that none of them will come within $4\frac{1}{2}$ inches of the brickwork enclosing a chimney flue. This is accomplished as shown in Fig. 44, the method of framing and the joints required having been already described. When there is to be a fireplace opening and hearth in front of the chimney, the trimmer *e*, Fig. 44, should be placed from 1 foot 9 inches to 2 feet 6 inches away from the chimney breast, in order to provide room for a brick trimmer arch. This method of framing with trimmers and trimming joists is also used round the openings for staircases, skylights, dormers, etc. A safe rule is to make the

trimming joists and the trimmers $\frac{1}{8}$ inch thicker than the regular joists for every joist carried by the trimmer. In actual practice, it is customary, however, to make the trimming joist and the trimmer 1 inch thicker than the joists carried by the trimmer. The ordinary floor joists may, however, be of such a scantling that it would be quite as economical to make the trimming

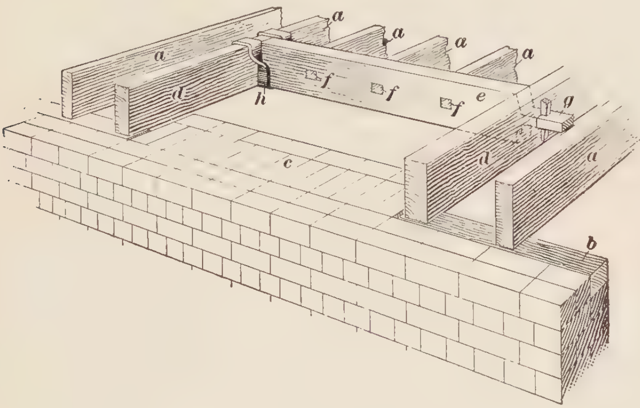


FIG. 44

joists *d* and the trimmers *e* of two thicknesses of ordinary joists spiked together. Fig. 44 also illustrates how the trimmer *e* may be supported on the trimming joist *d* by means of the stirrup *h*, instead of the mortise-and-tenon joint shown at *g*; *f* shows the tenons on the ends of the floor joists *a* which, when not trimmed for the hearth, rest on the wall plate *b*.

53. Floor Deafening.—Floor deafening may be accomplished in several ways. Fig. 45 shows a method of deafening by spreading a layer of heavy felt *a* over the floor joists *b*, over which are nailed 3″ × 2″ fillets or furring strips *c*. Another layer of felt *d* is laid over the fillets and the flooring *e* is laid over this. If there are two layers of flooring, it is advisable to interpose one thickness of felt between them. The felt laid over the beams and fillets is not drawn tight, but is allowed to hang loose, as shown in the figure.

In Fig. 46 is shown an improvement of an old method of deafening the floor by interposing some filling material between

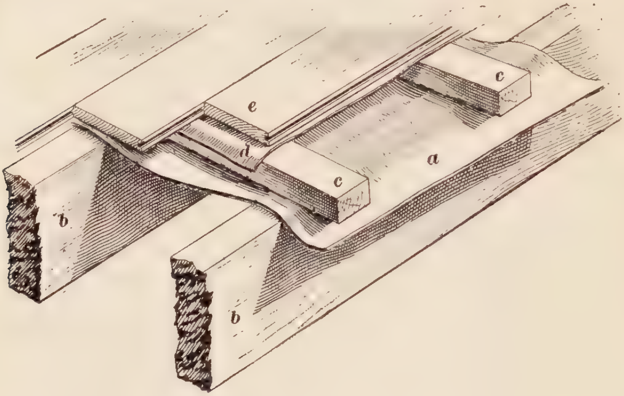


Fig. 45

the joists. In this case $1\frac{1}{2}'' \times 1''$ fillets are nailed to the sides of the joists, as shown at *a*. On these rest the sound boarding *b* which is cut with the grain at right angles to the direction of the joists. The space near to the tops of the joists is then filled

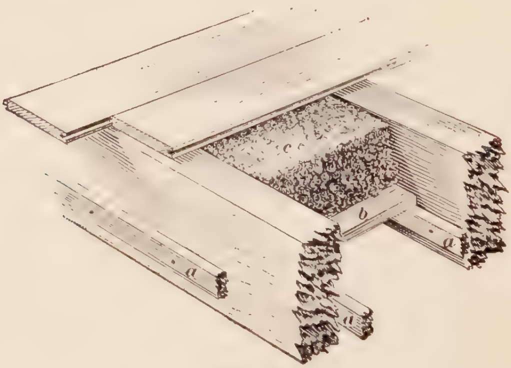


Fig. 46

with mineral or slag wool (silicate cotton) *c* and the boards of the floor are laid on the joists in the usual manner. The layer of slag wool may be only 3 or 4 inches in thickness, if desired.

An old method, which is still commonly executed, consists in coating the deafening or sound boards with a thin layer of

plaster, then filling in the space with dry engine ashes, and covering with another coat of plaster. Care should be taken that the top coat of plaster is clear of the under side of the flooring boards, to prevent dry rot in case of an insufficient dryness of the deafening material, or *pugging*, as it is called in this case. Fig. 47 shows another means of deafening by means of heavy felt *a* spread over the floor joists *b*, on which the floor boards *g* are laid, and tightly stretched and fixed in position by small fillets *c* nailed to the sides of the joists, thus forming a double air space *f*, *f* for the non-conduction of sound. Strips *d* of the same felt, and of a width corresponding to the thickness of the joists, are nailed to the under side of the latter before fixing the ceiling straps, or laths. These strips *d* are found to deaden, to a considerable extent, the sound that would otherwise be transmitted through the floor joists. Further, when the expense will permit it, the ordinary deafening or sound boards *e* can be inserted, as shown.

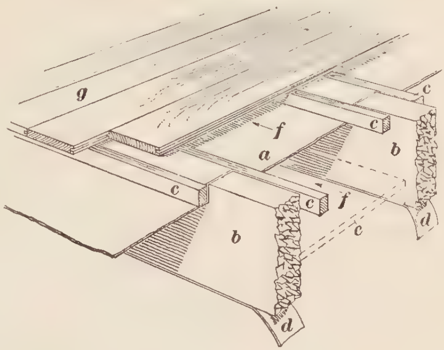


Fig. 47

54. Flooring.—The flooring is applied directly to the top of the joists after they have been brought to a true alinement, and may be jointed in various ways as the case and character of the building may require. A **plain** or **square joint floor** consists simply of second-quality boards nailed directly to the joists. Each board is from 6 to 10 inches in width and forms a plain joint edgewise with its neighbour. Such a floor is not used except in cheaper kinds of work or when a finished floor is laid over it. A **grooved-and-tongued**, or **matched, floor** is laid with selected material that has been grooved and tongued, or matched, as shown in Fig. 48 (*a*) and (*b*). This matching, though formerly worked entirely by hand, is now done by machinery at the mill,

where the material is cut up from seasoned timber. Matched flooring, therefore, is a commercial article purchasable at any timber yard.

55. When laid, grooved-and-tongued floor boards, $\frac{7}{8}$ inch and $1\frac{1}{8}$ inches thick, are from $\frac{1}{4}$ to $\frac{3}{8}$ inch narrower than the width at which they are purchased, which shortage represents the amount cut away in the milling. In Fig. 48 (*a*) are shown three pieces of matched 4-inch flooring, one piece of which, *a*, measures, when laid, only $3\frac{5}{8}$ inches, but the part *d* projects $\frac{1}{4}$ inch, making the total width of the board $3\frac{7}{8}$ inches, the remaining $\frac{1}{8}$ inch being lost partly in waste in the process of matching and partly by shrinkage after

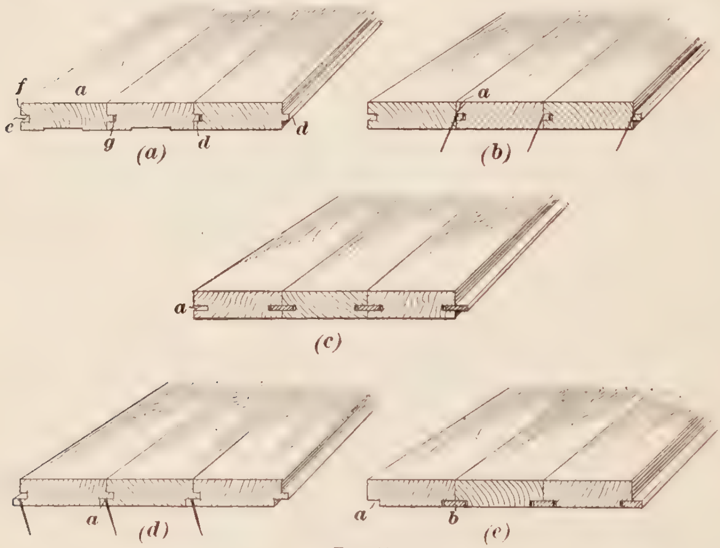


Fig. 48

the matching has been done. At one edge of the board, a projecting rib *d*, called the *tongue*, is cut, and on the opposite side a *groove c* is sunk a trifle deeper than the projection of the tongue. The upper edge *f* of the groove projects about $\frac{1}{32}$ inch more than the lower edge, so that when the flooring is laid and the groove is driven tight on to the tongue, as at *g*, the upper edge of the groove will then be driven tight against the upper shoulder of the tongue, thereby forming a tight joint on the surface. The same result is

obtained by keeping the under shoulder of the tongue slack, in which case the grooved edge would be square. The tongue is always placed slightly below the centre of the thickness, so as to give more wearing surface to the floor and render the edge of the groove less liable to curl. When this matched flooring is of hardwood, such as oak, maple, or teak, a shallow groove about $\frac{1}{32}$ inch deep may be cut along the under side, as shown. This enables the boards to be laid tight to the joists or under flooring, and causes them to be less affected by any slight unevenness of the substructure.

56. Matched flooring should always be **secret, or blind, nailed**; that is, the nails should be driven in the upper angle of the tongue, as shown at *a* in Fig. 48 (*b*), or as at *a* in (*d*). In the hardwoods, the nails should be punched in, so that their heads are well below the surface, and as the grooved edge of the next piece covers the tongue, it hides them from sight. In (*a*) and (*b*) boards are nailed only on the tongue edge, as the groove edge is held fast by the tongue. Next the wall, on both sides of the room, it is necessary to nail the first and last boards through the upper face.

57. There are other forms of joints, such as the **ploughed-and-tongued joint** shown in Fig. 48 (*c*); the **rabbeted grooved-and-tongued joint** shown in (*d*); and the **rabbeted-and-filleted joint** shown in (*e*). The ploughed-and-tongued joint, Fig. 48 (*c*), is useful where extra thick flooring is desired and consists in a narrow groove *a* being cut along the edge of each board into which is inserted a **tongue** of hardwood or iron. The rabbeted-and-filleted joint (*e*) has a hardwood or metal tongue *b* inserted in a groove *a* cut on the bottom edge.

58. Double Flooring.—**Double flooring** consists of a rough, plain, or matched floor of boards (preferably matched), laid when all the joists are in place and strutted, and of a second, or finished, floor of the character just described in detail, laid when all the rough work in the building is complete and when the joinery work is in progress. In first-class work the finished floor should not be laid until the skirting, window and door finishings

etc., have been fixed in place. Over the rough floor of a building all the coarse work is carried on, such as lathing, plastering, and the first coats of painting.

59. When two thicknesses of flooring are laid, a good method is to lay the first, or under, floor diagonally across the joists, as shown at *a*, Fig. 49. The second, or finished, floor is laid on top of this, but at right angles to the joists, as shown at *b*. When the rough floor is laid at right angles to the joists, and the finished floor runs in the same direction on top of it, the shrinking of the wide boards beneath may pull two or three of the boards of the finished floor up tightly together, thereby leaving open joints in the upper floor at regular intervals, corresponding very nearly with the widths of the rough boards below. The diagonal laying of the lower flooring obviates this difficulty, and to ensure an even bearing all round, it is sometimes necessary to nail between the joists, at their ends, some supporting pieces *m*, *m* to which the diagonal boards may be spiked. The rough floor should be well nailed to the joists, and care should be taken that the finished floor is nailed only over the joists; when driven into the boards only, the nails have little holding power and are liable to work loose. For floors $\frac{7}{8}$ inch thick, $2\frac{1}{2}$-inch cut nails should be used, and for $1\frac{1}{8}$-inch floors, 3-inch nails. In an apartment where there is a risk of water finding its way from the floor to the ceiling below, the system of

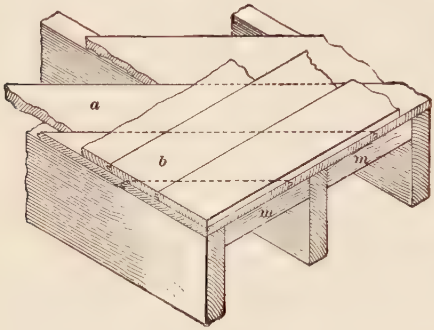


Fig. 49

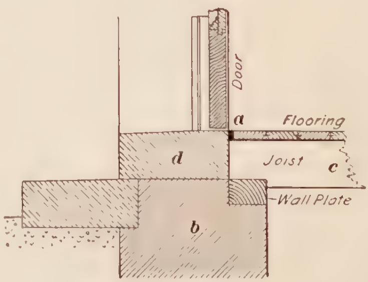


Fig. 50

double flooring might be used with a layer of asphalt felt laid between the rough and finished floors. In addition to stopping the percolation of water, the felt will serve as a deafening. The thicknesses of the boards in the lower and upper layers of a double floor are usually 1 inch and $\frac{7}{8}$ inch, respectively, but single floors in good dwellings should have the boards at least $1\frac{1}{8}$ inches thick. In mills, factories, warehouses, etc., the flooring varies from $1\frac{1}{8}$ to 3 inches in thickness. Where the stone sill *d*, bedded on the wall *b*, Fig. 50, of an outside doorway is butted up against the flooring, laid on the joist *c*, it is good practice to insert a metal tongue *a* This prevents an open joint being formed between the stone and the wooden floor by the constant traffic over the entrance step.

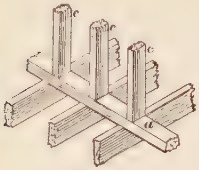
STUDDED PARTITIONS

SIMPLE AND TRUSSED PARTITIONS

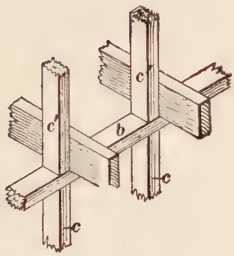
60. Partitions are constructed of pieces of timber from 4 inches by 2 inches to 6 inches by 3 inches in section, called **studs,** which are set vertically, with the depth of the stud in the direction of the thickness of the partition, and are spaced at 12- or 16-inch centres, in order to suit the lengths of laths they are to carry. Any difference in spacing that may be required should be made at one end of the room. Where the irregularity of spacing is caused by the insertion of a door or other opening, the difference should be made entirely on one side of the opening. Every spacing of studs that is a variation of the foregoing will cause the laths to project past, or fall short of, the nailing point for their ends, necessitating the cutting of the lath at the centre of the nearest stud, thereby wasting time and material.

61. All partitions that carry floor and roof joists should be, as far as practicable, continuous from basement or foundation walls to roof. Basements and ground floors often have brick walls that carry these bearing partitions, or they may have posts supporting girders on which rest the first tier

of joists. On these joists the studs of the ground-floor partitions should rest directly; the studs of the first-floor partitions should rest directly on the ceiling plate of the partition under it, as shown in Fig. 51 (*b*), and so on to the roof. This arrangement avoids the settlement of the upper floors, caused by the shrinkage of the joists, when the partition rests on the upper edges of the joists, as shown in Fig. 54.



(*a*)



(*b*)

Fig. 51

62. Where a partition is placed at right angles to the joists and does not occur over a partition under it, as shown in Fig. 51 (*a*), a sill *a* is first laid on the joists, and the studs *c* set thereon. Where a partition is at right angles to the joists and has a partition directly under, as shown in Fig. 51 (*b*), the studs *c′* rest on the ceiling plate *b*, which in turn is supported by the studs *c*. The studs are securely spiked to the sill and the plate.

63. In Fig. 52 is shown a method of forming the interior angles where partitions are placed at right angles to each other; *g*, *g′* are two studs of one partition and *h*, *h* are the studs of another at right angles to it. A board *f*, 1 inch thick and 3 inches wider than the stud *h*, is nailed to the stud and extends from the sill *a* to the top of the partition, thus affording a surface on each partition where the lath ends may be nailed, as at *d* and *e*. Strips may with advantage be secured in between the studs *g*, *g′*, to which the board *f* can be nailed.

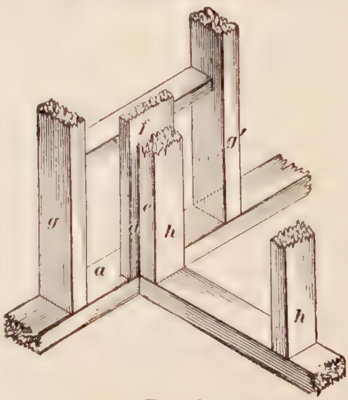


Fig. 52

64. Where a partition must come between two floor joists and parallel to them, it should have a head, as shown in

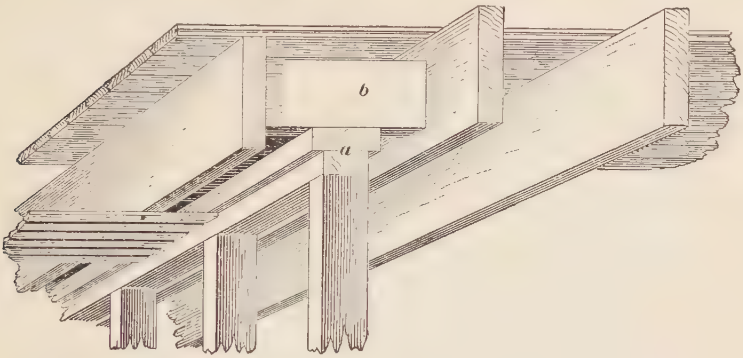


FIG. 53

Fig. 53, in which a double plate *a* is attached to blocking *b*, and a double joist for a base, as shown in Fig. 54, if it can be so placed.

All important partitions should be well supported at their foundations, either by a brick wall or by a beam carried on brick piers or wooden posts, with proper foundations.

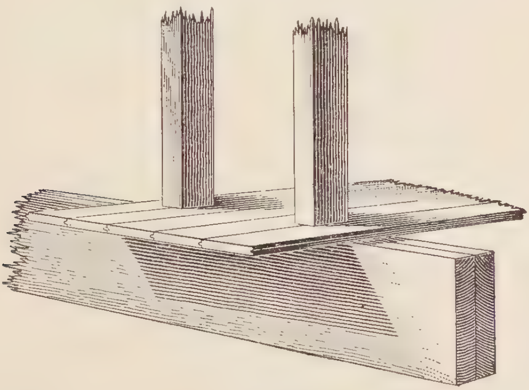


FIG. 54

65. Deafening.—The deafening of a plastered partition may be accomplished as shown in Fig. 55, where the partition studs

are shown at *c* to which fillets *b* are nailed. Laths are fixed to these fillets in between the studs, and are finished over with a coat of plaster, as shown at *a*. At *d* and *g* are shown the laths to the outside of the studs, to which the plastering *e* and *h* is affixed to form the finished face of the partition, while at *f* is shown the skirting to the room securely fixed to grounds to stop the plaster.

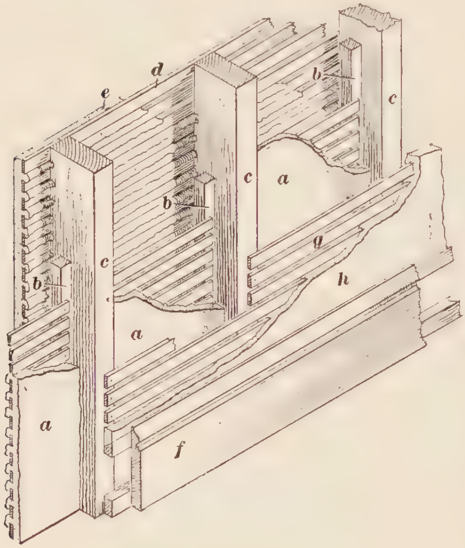


Fig. 55

66. Lathing.—Lathing is applied to the partitions as soon after the studs are in place as is convenient. Where pipes or wires are to be carried within the partitions, it is sometimes necessary to delay at least a portion of the lathing until they are in place, or, when the exact position of these interior lines is determined on, the laths may be left off one side of the partition until the wiring or pipe lines have been inserted. When lathing is applied to the ceiling of a room, it is sometimes nailed directly to the under side of the ceiling joists, though in first-class jobs it is always best to provide some means of bringing the bottoms of the ceiling joists to a level alinement before the laths are nailed on. Laths consist of strips of soft wood, generally 1 inch wide, $\frac{1}{4}$ inch thick, and 48 inches long. They are laid horizontally on the partitions, nailed to each stud, and maintained, as nearly as possible, at a uniform distance apart, usually from $\frac{1}{4}$ to $\frac{3}{8}$ inch, as shown at *g*, Fig. 55. To guard against unsightly cracks in the plaster at the angles of rooms, suitable nailing strips *d*, *c*, Fig. 52, or double studs, as *a*, *b'*,

Fig. 60, must always be provided. Under no circumstances must the laths be permitted to extend across from one stud to another behind the end of a partition, as from g to g', Fig. 52.

67. Plaster Grounds.—Where any woodwork is to be applied against a plastered wall, such as a skirting, chair rail, wainscot, picture moulding, etc., it is always necessary to provide a proper bearing to nail the woodwork against, in order to avoid cracked plaster and insecure fastening, which would result from nailing through to the lath and plaster into the stud. Therefore, a **ground** is nailed against the studding at such a height as the top of the skirting, or other finishing, will reach, and of a thickness equal to that of the laths and plaster. To this ground the finishings are fastened when the plastering is finished and dry. When the finishing to be applied is in the form of a wainscot or other wide surface, it is sometimes necessary to have several grounds at different heights, to which the separate pieces may be attached. It is always desirable in first-class work to have the walls below the grounds finished with one coat of plaster down to the floor line, as the back of the woodwork is thereby protected from exterior dampness and draughts, and vermin have less opportunity to make passages between the finishings and the walls. It is essential, however, that the plaster should be thoroughly dry before the woodwork is placed in position, for if unseasoned wood is used the dampness from the plaster will be absorbed partly by the woodwork and twisting and buckling will follow, and dry rot may occur.

68. Though the primary purpose of grounds is to form suitable nailing places for interior finishings, they, at the same time, form a stop for the plaster. If no grounds are provided, and the plaster is simply carried to some arbitrary point that will be hidden behind the finishings, an insecure job results and the edges of the plaster are liable to break off and crack as the woodwork is put in place, thereby necessitating patching and repairing after the job is complete. However, if a ground is placed at every side where the plaster will stop, the entire wall surface is enclosed in a frame and is secure from damage.

69. Brandering, or Cross-Furring.—Since floor joists are notched, so as to be in alinement at the top, any irregularity in the depths of the joists will, by this method, be thrown to the under side. Therefore, when the under side of these joists is to carry a plastered ceiling, they must first be levelled by a system of brandering. This is accomplished by nailing thereon branders or furring strips about 1 inch by $1\frac{1}{4}$ inches, and spacing them at from 12 to 14 inches on centres. These branders are either nailed to the joists or dropped below them by the insertion of slips to bring them in line. The laths are then nailed on these branders. When a ceiling is brandered, it is more rigid; the plaster is less liable to crack by the vibration of the joists, and, being generally of less width than the thickness of the joists, a better key is secured for the plaster.

70. Trussed partitions are sometimes necessary where there is no supporting partition in the story below, or where a partition has so many doors or other openings through it that it is too

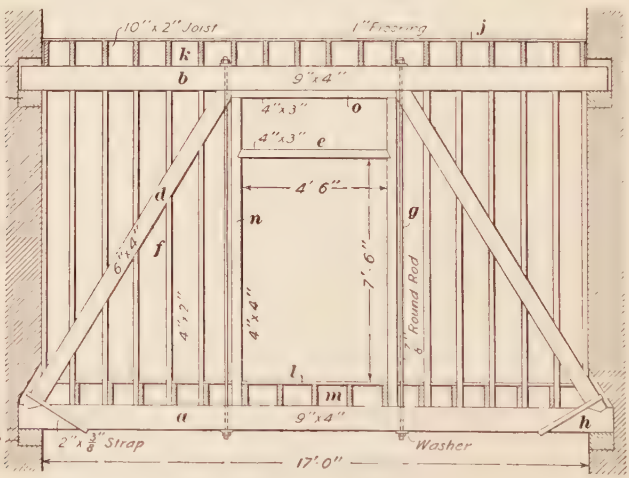


Fig. 56

weak to safely carry the required weight to be imposed on it. Fig. 56 shows a trussed partition with a 7′ 6″ × 4′ 6″ door opening in the centre of it. The sill *a* and the plate *b* are

made 9 inches by 4 inches. The studs *n* at each side of the door opening are 4 inches by 4 inches and the head *e* is 4 inches by 3 inches, as also is the head of the fanlight opening *o* over the door opening. From the ends of the timber *n* the braces *d* extend to the ends of the sill *a*, where they are let in at *h*, and held by the iron straps to secure them from slipping. A truss is thereby framed, round the members of which the 4″ × 2″ studs *f* are cut. This truss is further strengthened by means of the iron tie-rods *g*, which prevent the sill *a* from sagging. The entire weight of this partition, together with any superimposed load, will come on the templates *c* and *i* on both sides, where ample support must be provided to carry the weight down to a proper foundation. At *k* are shown the joists of the floor over, with the floor boarding at *j*; while the joists *m* rest on the sill *a*, and are finished with the floor boards *l*.

71. Fig. 57 illustrates a partition with three openings. The essential difference between it and that shown in Fig. 56 is that

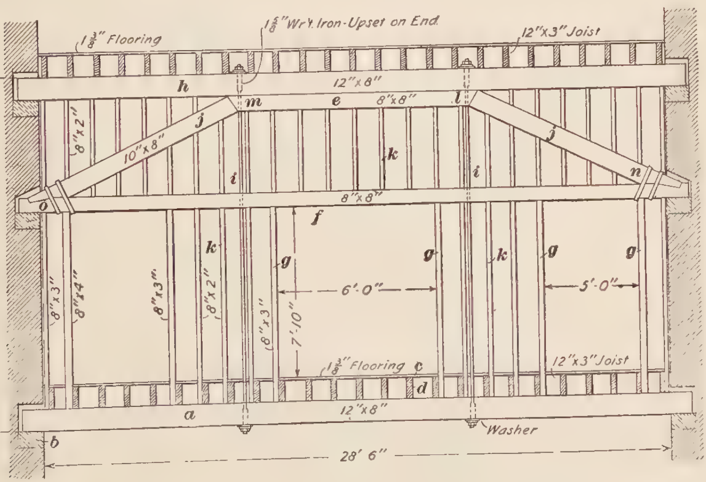


FIG. 57

the truss is entirely above the openings, while in the former example the opening was through the centre of the truss. In Fig. 57 is shown the sill *a*, held up by the iron tie-rods *i*. The

tie-beam *l* marks the top of the openings, and into it the rafters, or struts, *j* are notched at each end, as at *o* and *n*, with the compression member *e* between their tops. At *h* is the head of the partition carrying the joists of the floor over. This entire truss *o m l n* is carried by the walls, the horizontal members or sills resting on stone templates *b* bedded into same. At *k* is shown the partition studs fitted in between the members of the truss and the head and sill, and at *d* are the floor joists resting on the sill *a* with the flooring *c* finishing on top of the joists.

72. Door Openings.—Door openings more than 3 feet wide, over which run the floor joists, should have their heads trussed, as shown in Fig. 58, the head *c* resting on the studs *d*, and the struts *e* footed into the head. This prevents the top of the door from sagging in the centre, as the superimposed load is all carried to the side studs *d*. At *a* and *b* are shown the general studs of the partition. Double studs, or larger-sized studs, should therefore always form the sides of door openings, as shown at *d*, for the purpose of gaining strength and also to afford a nailing space for the finishings, and a stop to the plaster. When a single piece of timber of the proper size for this is not at hand, it is customary to spike together two pieces of the ordinary studding and use them as a double stud, as shown at *d*.

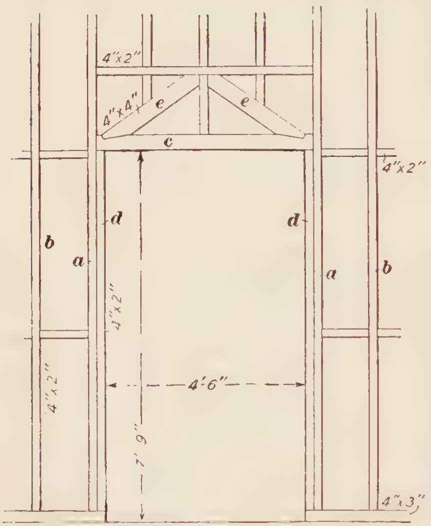


FIG. 58

73. The sizes of doors as marked on plans or working drawings should be the dimensions of the finished parts. Therefore, in framing the openings for them in the studding, an allowance must be made. In door openings, false jambs are sometimes

inserted, as shown in Fig. 59. These jambs are nailed to the studs, and the plaster finished to them, in order to make the sides of the opening perfectly vertical and the top level. Therefore, an allowance of about 6 inches in width and 3 inches in height is required in framing the stud openings for doors, and an ordinary door, 7 feet by 2 feet 10 inches, will require a framed opening 7 feet 3 inches by 3 feet 4 inches. When setting the finished jamb, solid blocks *c* should be placed where the hinges of the door will come, as shown in Fig. 59. At *d* is shown the partition studs resting on the sill *b* with lathing *g* fixed over same, and the ground for skirting at *a*.

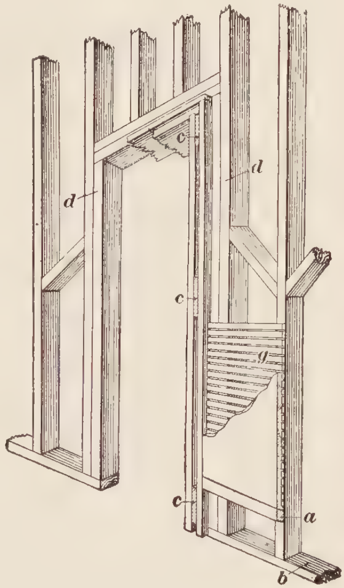


FIG. 59

FRAME BUILDINGS

SILLS, POSTS, AND STUDS

74. **Frame buildings** are not much used in the British Isles, except for temporary structures, but they are used to a very great extent in America and the Colonies.

75. **Sills.**—The carpentry work in a frame building usually commences when the foundation is completed. First, a timber, called the **sill**, *a*, Fig. 25, is laid and bedded in haired mortar on the top of the foundation wall to receive the superstructure of wood. This sill varies from 8 inches by 6 inches to 10 inches by 8 inches in regular or brace-framed buildings, from 6 inches by 4 inches to 8 inches by 4 inches in balloon-framed buildings ; and

is laid 1 inch, or the thickness of the sheathing, from the outer face of the foundation wall. The corners of the sill are halved, as shown in Fig. 20, and when a longer run of wall has to be covered than can be accomplished by one piece of the timber, the bevelled halved joint, shown in Fig. 21, is generally used.

76. The **corner posts** *b*, Fig. 25, are then erected at the angles of the building. These are usually composed of from 8″ × 6″ to 10″ × 8″ timbers in regular frames, and of from 6″ × 4″ to 8″ × 6″ timbers in balloon frames, according to the width of the studs. In regular frames the lower end of the corner post is generally mortised into the sill at the halved corner, and its upper end is mortised into the plate *h*. In balloon-framed work the corner posts are simply butt-jointed and spiked to the sill and the plate, the internal angle being formed by spiking a stud to the face of the corner post.

77. The **studs** *k*, Fig. 25, are sometimes mortised into the sill *a*, into the girt, or intertie, *d*, and into the plate *h*, although in modern work they are more frequently simply butt-jointed in position, except in the case of double studs at the sides of openings. In balloon-framed work, however, the studs should always extend from the sill to the plate, in one piece, if possible. Where the height is too great, they may be spliced in the manner shown in Fig. 8. To carry the floorjoists in the first or second floors of a balloon frame, a *ledger board* is notched into the studs, each beam being spiked to the adjacent stud. In regular frames the upper floorjoists rest on the intertie, as shown at *i*, Fig. 25.

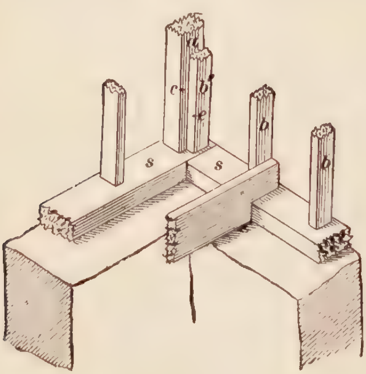


Fig. 60

78. In Fig. 60 is shown a method of securing a firm internal angle at the corner of a building; *a* is the corner post of a building resting on the sill *s*, and *b*′, *b*, *b* are the studs of

the outside wall. The corner post in this case is made of a $6'' \times 4''$ piece *a*, while a $4'' \times 2''$ stud *b'* is spiked to it flush with the outside. This arrangement leaves the two surfaces *c* and *e* to which the ends of the lath of each wall may be securely nailed.

79. Where well-seasoned material can be obtained, it is customary to set the first-floor joists directly on the beam over the cellar, as shown in Fig. 61. When this is done, it is well to

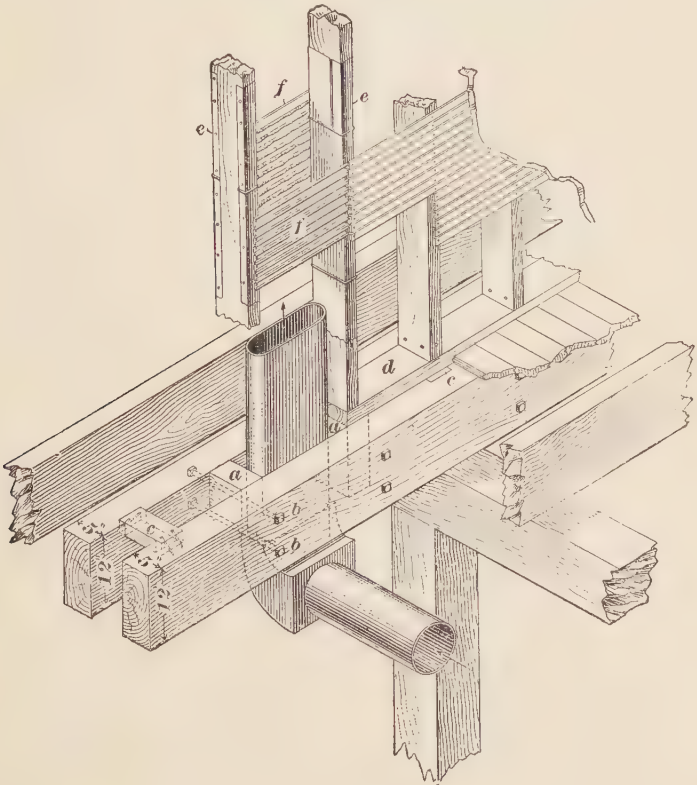


Fig. 61

keep the joists ¼ inch higher over the beam than at the walls, to allow for subsequent shrinkage of the beam. It is shrinkage of material that causes new houses to settle, and if the settlement

is uniform, no harm results; but irregular settlement causes uneven floors, cracked plaster, and doors and windows that refuse to open readily or close tightly. Good, sound, well-dried material, therefore, should always be used, when such is obtainable, and all unsound, warped, knotty, sappy, or shaky timber should be rejected.

80. Ventilating Ducts and Pipes in Partitions. In Fig. 61 is shown a method of supporting a partition parallel with the floor joists, as well as allowing a space through which to run a duct. Two 12″ × 5″ beams, or such size as the conditions require, are laid with a 6-inch space between and are bolted together through 6″ × 4″ blocks *a*, with $\frac{3}{4}$-inch bolts *b* at every second stud; 4″ × 2″ pieces *c* alternating with the blocks mentioned, except where the duct occurs, are notched into the beams and nailed. In cases where the cost is a consideration, the bolts may be omitted and the blocks simply spiked in place, relying on the cross-bridging for support in opposite directions. All blocks are put in on a level with the top of the beams. A 6″ × 2″ sill *d*, on which to foot the partition, is laid on these blocks. This sill is cut between the studs, where it is desired to run the tin heating duct, thus allowing the duct to run through the partition between the studs. The studs and all woodwork round the duct, if it is a heating duct, are generally covered with some sheet metal, or other fire-resisting material, *e*, to protect the wood from the heat. Metal laths *f* are also used between the studs where the duct runs; this prevents the possibility of a fire, which otherwise is liable to occur should the duct become very hot. The duct should also be covered with asbestos lining, so that it will communicate as little heat as possible to its surroundings.

81. Partition Deafening. The deafening of a plastered partition may be accomplished by inserting a layer of heavy felt between the studs that support the faces, as shown in Fig. 62. The studs *a*, *a′* are 4 inches by 2 inches, and are spaced at 12-inch centres for sheathing, and at 8 inches for plastering. However, instead of being set to an even line, every second stud *a* is placed 2 inches behind the line of the studs *a′*, and the

sheathing *b* is nailed to every second stud only, thereby making each side of the partition practically a separate structure. Before the sheathing is applied, one or two layers of heavy building felt *c* should be woven between and secured to the studs, as

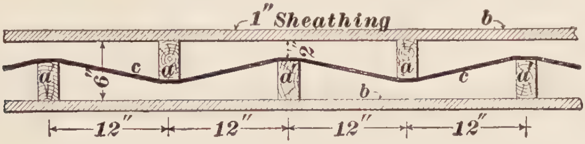


Fig. 62

shown, in order to absorb any sound vibrations that may pass through the sheathing. This felt should be very heavy, about 9 square feet to the pound, and should not be drawn tight from stud to stud, but simply laid in somewhat slack and tacked in place on each stud.

82. **Door and Window Openings.**—The framing for door and window openings in a framed building is similar in most respects to the method adopted for making openings in an interior partition before described. Care must be taken that the opening is framed of the correct size to take the joinery finishings specified.

CARPENTRY

(PART 3)

ROOF CONSTRUCTION

TYPES OF ROOFS AND ROOF FRAMING

1. Pitch.—A **roof** may contribute much to the elegance and completeness of any building, as, by its fitness and appropriateness of outline, and its harmony with the structure, it crowns the whole. The angle to which any roof may be constructed is variously designated as **pitch, slope,** or **inclination.** The pitch may be designated by the number of degrees of inclination; the usual method, however, is to state the proportion between the vertical height of the ridge and the span of the building. Thus, if the height is 8 feet and the span 24 feet, the roof is said to have a *one-third pitch.*

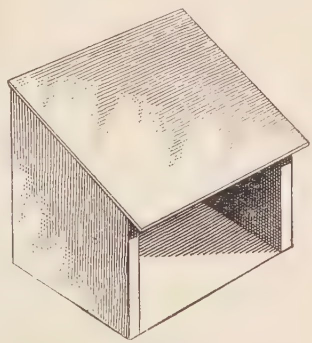


FIG. 1

2. Flat and Single Pitch.—According to the manner of pitching a roof in one or more directions, there is given to it a particular name, which may express the character of the whole roof or merely name one of its characteristics. A **flat roof** is one in which there is only a slight pitch, or slope, to its timbers, just sufficient to cause water to run to its lower edge, which is called the *eaves.* The amount of pitch usually given to a flat roof varies

from $\frac{1}{4}$ inch to 3 inches to a foot, according to circumstances. When the inclination of the roof materially exceeds 3 inches to the foot, the roof comes under the class of **single-pitch,** or **shed, roof,** sometimes called a *lean-to,* as shown in Fig. 1. This kind of enclosure is usually built against the side of another structure already erected, hence its name, *lean-to,* and its roof often has to receive and carry the drippings from the main roof above, as well as its own collection of moisture. The single-pitch roof, however, is also frequently used over verandas, attic dormer-windows, and in other minor positions on the main building.

3. **Double Pitch.**—When the pitch falls in both directions from the centre of the building, it forms what is known as a **double pitch,** or **gable, roof,** as shown in Fig. 2, the plan of which is the rectangle *f g h i*. This form of roof derives its name from the shape of its ends, the triangle *a b c* being called a *gable*, one of which exists at each end of the building. The upper edge of the roof *b e* is called the *ridge,* and the lower edges, on each side, as at *a* and *c d*, projecting beyond the lines *f i* and *g h* in the plan, are the *eaves,* while *j k* shows the position of the ridge *b e*. In Fig. 3 is shown the perspective of a double-pitch roof supported by kingpost trusses. The walls are extended up at the eaves line, instead of the roof projecting over as shown in Fig. 2.

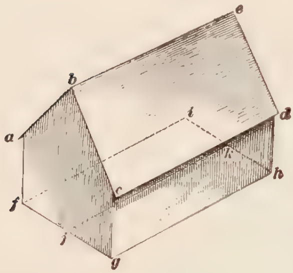


FIG. 2

4. **Valleys.**—Fig. 4 (*a*) shows, in perspective, a square structure with a gable on each of the four sides. The ridges of these gables intersect at *o*, while the eaves intersect in pairs at *a*, *c*, *e*, etc.; the line of intersection *o c* between the pitches *d c* and *b c* is called a **valley.** In (*b*) is shown a plan of this roof, in which the lines *d′ h′* and *f′ b′* mark the positions of the ridges; the lines *o′ a′*, *o′ c′*, *o′ e′*, and *o′ g′* show the intersections of the sloping surfaces, called *valleys*, while the dotted outline *g′ i′ a′* is the form of the elevation of the gable over *g′ h′ a′*.

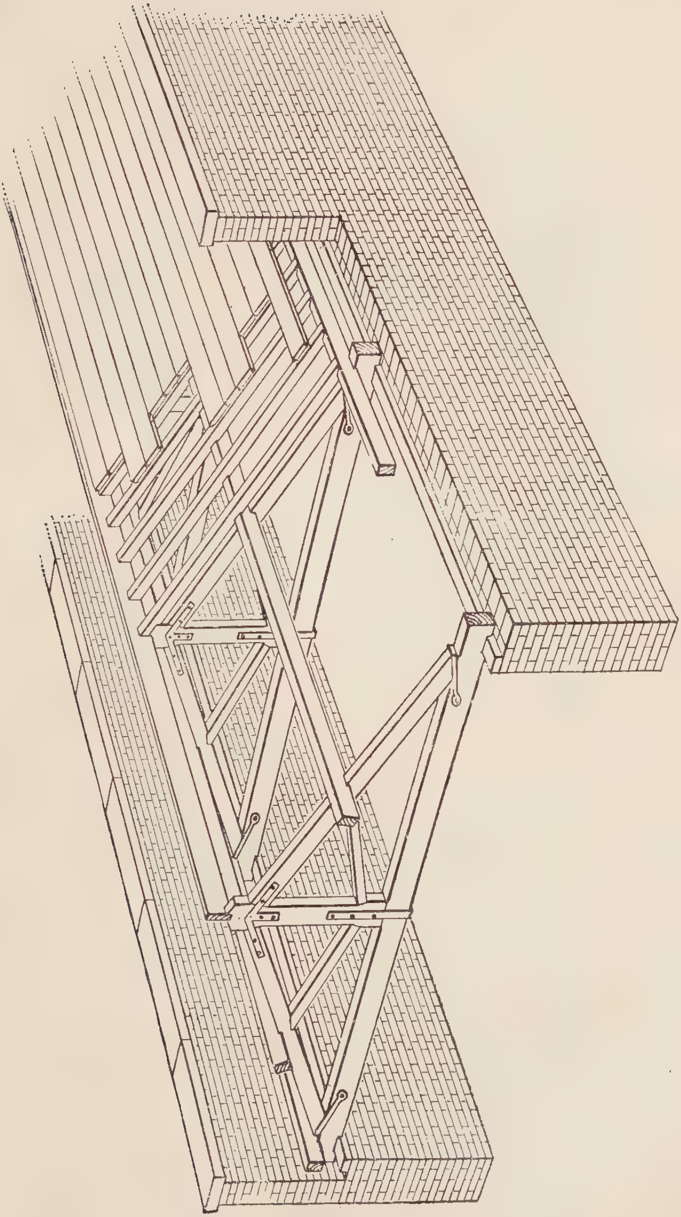


FIG. 3

5. **Hip Roofs.**—In Fig. 5 (*a*) is illustrated a rectangular building with a roof pitched back from all four sides, forming a pyramid. The edges *o a*, *o b*, and *o d*, where these pitches meet, are called *hips*, and this type of roof is known as a **hip roof.** As the building is not square in this case, the pitch of the side *a o b* is different from the pitch of *a o d*, because the point *o'*, as seen in the plan (*b*), is the intersecting point of all four sides (called the *apex*) and is farther from *f'* and *h'* than from *e'* and *g'*. Therefore, the proportion of rise to run is different in adjacent sides, and the pitches are necessarily different. In the plan of this roof, shown in (*b*), the lines *a' c'* and *b' d'* show the position of the hips intersecting at *o'*. On the dotted line *o' e'* is set off the distance *o' k'* equal to the height of the roof at the centre *o'*; then, the lines *k' f'* and *k' h'* show the pitch of the rafters, which are parallel with *o' f'* and *o' h'*. Likewise, when *o' i'* is set off equal to the height of the centre point *o'*, the lines *i' e'* and *i' g'* give the pitch of the rafters over, and parallel to, *o' e'* and *o' g'*.

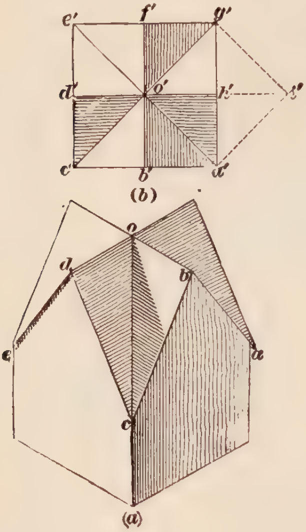
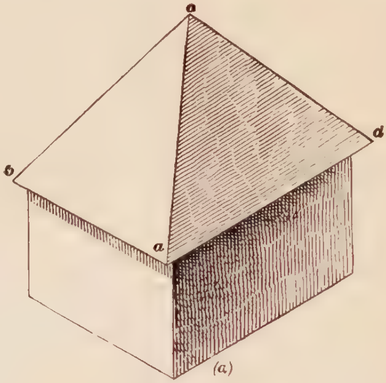


FIG. 4



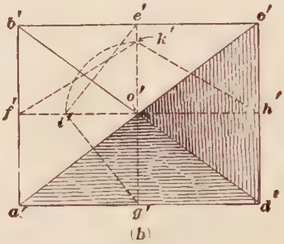


FIG. 5

6. Gable-and-Valley Roofs.—In Fig. 6 is shown the plan of a **gable-and-valley roof.** The four gables *t z s* are precisely similar to the four gables in Fig. 4, but are brought forward from the sides of the square *a a′ a a′*, giving the building the form of a cross, as shown. The dotted line *z v* is drawn equal to the height of the ridge *z z* above the eaves, and the lines *v t* and *v s* are then drawn, giving the pitch of the gables. If, on *x a*, the valley line, *x o* is set off equal to the height of the ridge and *o a′* is drawn, then *o a′* will be equal to the length of the valleys *x a* and *x a′*.

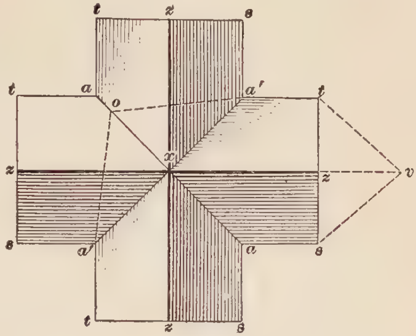


FIG. 6

7. Hip-and-Valley Roofs.—The **hip-and-valley roof** in Fig. 7 is, in outline, precisely the same as the roof in Fig. 6, but in its plan of construction it has no gables. The four ends of the two parallelograms forming this plan have each two hips, as at *x r*, eight altogether, and there are four valleys, *z s*, *z m*, *z n*, and *z a*, with two ridges, *x x′* and *b b′*. If, now, *x t* and *x′ t′*, each at right angles to *x x′* and equal to the height of roof, are drawn, and the elevation of the ridge *t t′* is connected with *g* and *g′*, a vertical section of the roof *g t t′ g′* on the line *g g′* is obtained. Now, if *z e* is drawn equal to *z o*, the height of the roof, and *e m* and *e a* are connected, a vertical section of the roof valleys *z m*, *z a* is obtained at *m e a*. To obtain a vertical section of the roof through *m n*, *b′ h* is made equal to the height *x t*, and *h m* and *h n* are connected.

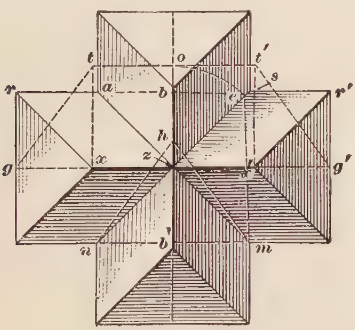


FIG. 7

8. Mansard Roof.—The **Mansard roof** is so called from the French architect Mansard, who invented it. The top part has a low pitch, but the lower part has a very steep pitch. The reason for this form is to give more space in the attic, or garret, of a building by increasing the height near the eaves, where an ordinary pitched roof gives no headroom. This term was originally applied only to roofs having this form on all sides, but it is now as often given to roofs having gables at the ends also. In America and the Colonies, however, a distinction is made between the two types, the one having the gable form at the end being known as a **gambrel** roof; sometimes it is called a *curb roof*. The term *gambrel* signifies a bend, or crook, and in this case emphasizes the break in the continuity of the roof plane. In Fig. 8 the rise *f d* is equal to one-half the span *b a*, which is the common proportion of the gable-end roof. In framing this roof, it is always necessary to have a plate, or curb, at *e h*, as well as at *a i*, and the rafters between these points must be cut to foot on *a i* and to carry the plate at *e h*. The rafters between the ridge *d g* and the plate *e h* are cut in the same manner for ridge and plate as in an ordinary gable roof. The plate *e h* is securely tied across the building to keep it from spreading under the thrust.

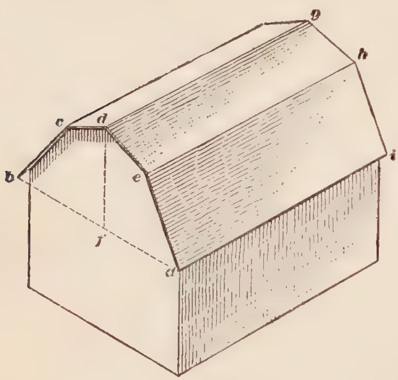


Fig. 8

9. Where the wings of a building are unequal in width, the uniformity of pitch and equality in the height of the ceiling joists may be preserved by the method shown in Fig. 9. In this case, the front wing is 28 feet wide and the side wings are 18 feet wide. The method of proportioning the gables according to Belidor's rule is shown in Fig. 10. The line *a f* is made equal to the width of the front, plus 18 inches for each eaves projection,

making 31 feet. On the centre *g*, with a radius equal to one-half of this measurement, describe a semicircle *a h f*; divide this semicircle into five equal parts, as at *b, c, d,* and *e,* and erect

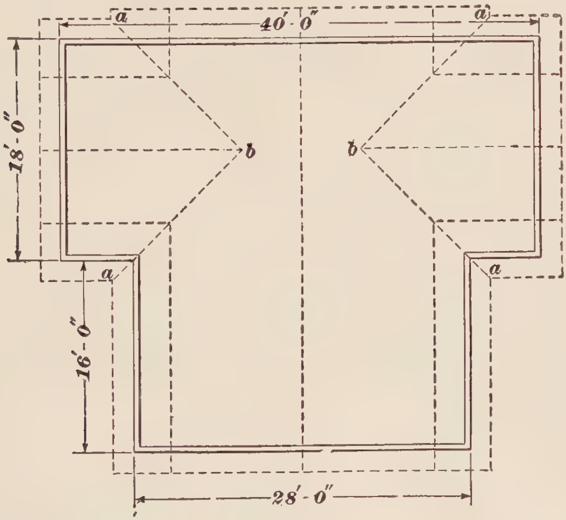


FIG. 9

the line *g h* perpendicular to *a f*. Draw *a b* and *f e,* the side slopes of the roof, and *b h* and *e h,* the upper slopes of the roof; then, *a b h e f* will be the outline of the gable over the front and

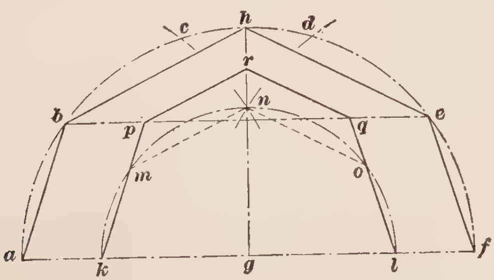


FIG. 10

rear of the house. The gables over the 18-foot wings, if set out in the same manner, would give an outline as at *k m n o l*; this outline would be undesirable, as the slopes would not intersect

properly and a uniform height of ceiling would not be obtained. If, however, the side pitch *k m* is continued up to the curb line of the main roof at *p*, and *p r* is drawn parallel with the upper slope of the main roof, the outline *k p r q l* will be suitable for the roofs over the wings, and the ceilings will be the same height as in the main part of the house. Both roofs will have the same pitch, and their intersection on the plan will be at an angle of 45° with the sides of the house, as at *a b*, Fig. 9. The dotted lines in Fig. 9 denote the roof plan.

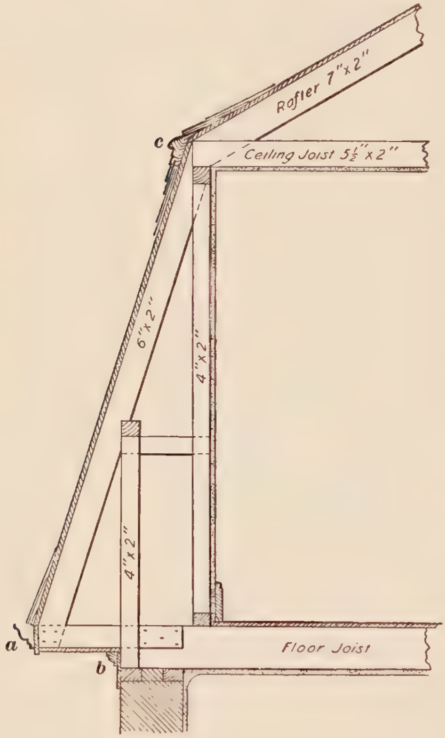


FIG. 11

10. Fig. 11 shows the construction and finish of the roof in Fig. 12. The angle between the soffit and frieze is finished with a bed moulding *b*, while the cornice *a* at the eaves, which are given a liberal projection, consists of a moulded gutter and fascia. The cornice is continued up the slope of the gables with a similar moulding to that formed by the gutter, and fascia on the sides, while the fascia and fillet of the corona, or lower members of the cornice, are carried across the front horizontally, as shown in Fig. 12. The method of slating or tiling the roof at the curb is shown at *c*, Fig. 11. The slates or tiles of the upper slope are laid with a slight projection beyond the edge of the moulding *c*. The latter closes the angle at the curb line, and is laid over the slates on the lower slope.

11. The other type of Mansard roof, Fig. 13, resembles

FIG. 12

the type just described in having a very flat top *a b c d* and very steep sides *a d f e* and *d c g f*, but, instead of being enclosed with gables, it is the same on all sides, therein somewhat resembling the hip roof. The sides of the regular Mansard roof are often, though not always, curved, and are much more nearly perpendicular than the sides of the gambrel roof, as, in reality, these lower slopes of the Mansard are nothing more than continuations of the side walls of the building. In fact, the distinguishing characteristics in the two forms of Mansard roofs may be said to be that the gable-end roof is an endeavour to make the inside of the roof appear like an upper story, while the other form is an effort to make the outside of the upper story look like part of the roof. From the fact that the

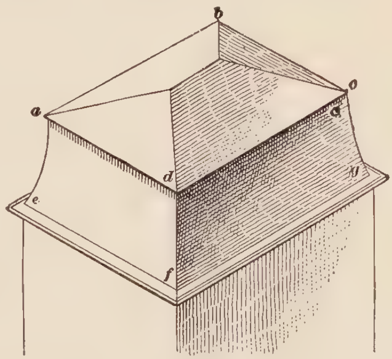


FIG. 13

wings of large buildings, called *pavilions*, are often covered with this form of roof, the Mansard roof is sometimes termed a *pavilion roof*. The relative pitch of the top and side slopes of these roofs may be determined in several ways, one of which is shown in Fig. 8, where the rise *f d* of the roof is equal to one-half the span *a b*. Variations from this rule are common in practice, but these proportions are such as will usually give most satisfactory structural results.

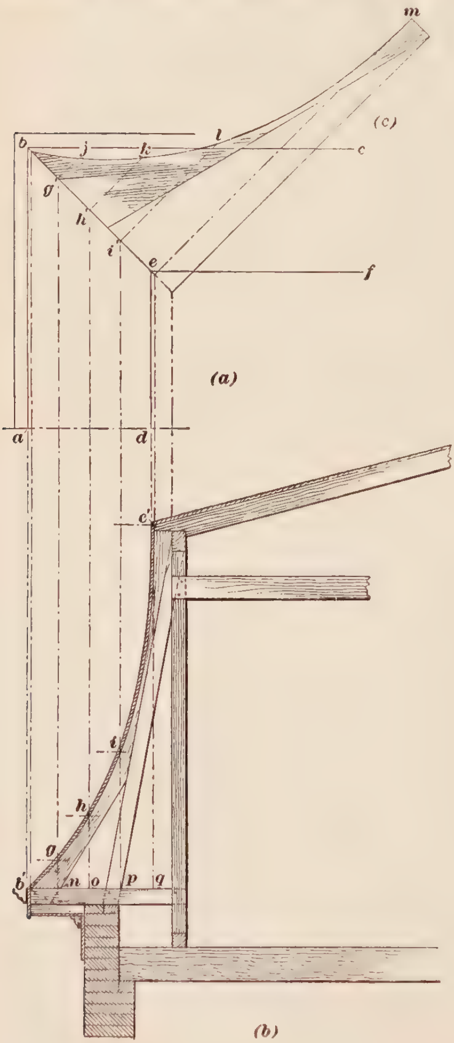


FIG. 14

12. In Fig. 14 is shown a plan (*a*) and a section (*b*) through the lower slope of a Mansard roof, while at (*c*) is shown an elevation of the angle rib at *a e* or *d f*, Fig. 13. In the plan (*a*), *a b c* is a corner, or angle, of the building at the lowest portion of the sloping sides of the roof, and is designated in the section (*b*) by *b′*. The line *d e f* in the plan is the upper edge of the sloping side and is designated in the section by *e′*. If, in the section, any number of points, such as *g*, *h*, *i*, are projected up from the curved side,

and their intersections with the mitre line of the hip $b\,e$ are marked at g', h', i', and from these points and at right angles to $b\,e$ the lines $g'\,j$, $h'\,k$, $i'\,l$, and $e\,m$ are set off equal to $n\,g$, $o\,h$, $p\,i$, and $q\,e'$ the heights of the points g, h, i, and e' above the level of the main slope at b' in the section, points j, k, l, and m in the curve of the angle rib will be obtained, and these points, if connected by a curved line, will give the profile sought.

TRUSSED ROOFS

SIMPLE TRUSSES

13. Couple Roof.—What is probably the simplest form of roof truss is shown in Fig. 15. It is known as the **couple roof** and consists principally of two rafters a, a, the feet of which are notched to the wall plates b, b, to which they are nailed. The heads of the rafters butt against the ridge board c to which they are nailed. The inclination of the rafters varies but for slate roofs the rise is usually equal to one-quarter of the span. The sizes of scantling given in Table I will usually be found to give excellent results.

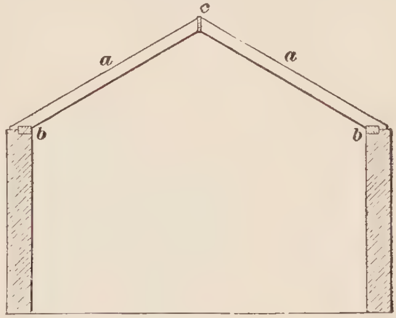


FIG. 15

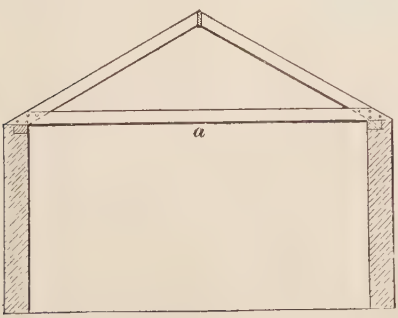


FIG. 16

14. Couple-Close Roofs. In couple roofs, the rafters have a tendency to push out the side walls of the building, therefore, it should not be used on a span greater than 12 feet without some precaution being taken to receive the thrust of the rafters. One

method of avoiding this thrust is to use a ceiling joist *a*, Fig. 16, the sizes of which are given in Table I. This ceiling joist is often

TABLE I

SCANTLING FOR COUPLED ROOFS

Span from Centre to Centre of Wall Plates Feet	Rafters *a* Inches	Ridge Board *c* Inches	Ceiling Joists, if Used Inches
8	3 × 2	7 × 1½	4 × 2
10	3½ × 2	7 × 1½	5 × 2
12	4 × 2	7 × 1½	6 × 2
14	4½ × 2	7 × 1½	7 × 2
16	5 × 2	8 × 1½	8 × 2
18	5½ × 2	8 × 1½	9 × 2

called a *tie-beam*, and a roof in which it is used, as shown in Fig. 16, is called a **couple-close roof.**

15. Collar-Beam Roofs.—Where it is desired to have more headroom in buildings than the couple-close roof allows, the tie is placed half-way up the rafters, as shown in Fig. 17. The tie *a* is called a *collar*, and the roof is known as a **collar-beam roof,** but this construction is not considered very strong. The dimensions of the timber vary according to whether the wall can take any thrust from the rafters or whether all the thrust must be carried by the collar, and also whether any ceiling is used. The dimensions of scantling to use when the pitch of the roof makes an angle of 30° with the horizontal are given in Table II.

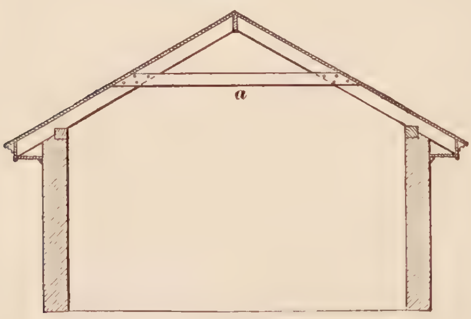


FIG. 17

TABLE II

SCANTLING FOR COLLAR-BEAM ROOFS

Span	Rafters				Collars	
	Thrust Taken by Walls		Thrust Taken by Collars			
Feet	No Ceiling Inches	Ceiled to Collars Inches	No Ceiling Inches	Ceiled to Collars Inches	No Ceiling Inches	Ceiled to Collars
8	$2\frac{1}{2} \times 1\frac{1}{2}$	$3 \times 1\frac{3}{4}$	$3\frac{1}{4} \times 2\frac{1}{4}$	$3\frac{3}{4} \times 2\frac{1}{4}$	$2\frac{1}{2} \times 1\frac{3}{4}$	2 inches wide by $\frac{1}{2}$ inch, more than $\frac{1}{2}$ inch per foot of clear length of underside of collar.
10	$2\frac{1}{2} \times 1\frac{3}{4}$	$3 \times 1\frac{3}{4}$	$4 \times 2\frac{1}{4}$	$4\frac{1}{2} \times 2\frac{1}{4}$	$2\frac{1}{2} \times 2$	
12	$2\frac{3}{4} \times 1\frac{3}{4}$	$3\frac{1}{4} \times 1\frac{3}{4}$	$4\frac{1}{2} \times 2\frac{1}{4}$	$5 \times 2\frac{1}{4}$	$2\frac{3}{4} \times 2$	
14	$3 \times 1\frac{3}{4}$	$3\frac{1}{2} \times 1\frac{3}{4}$	$5 \times 2\frac{1}{2}$	$5\frac{1}{2} \times 2\frac{1}{2}$	3×2	
16	$3\frac{1}{4} \times 2$	$3\frac{3}{4} \times 2$	$5\frac{1}{2} \times 2\frac{1}{2}$	$6 \times 2\frac{1}{2}$	$3\frac{1}{2} \times 2$	
18	$3\frac{3}{4} \times 2$	$4\frac{1}{4} \times 2$	$6 \times 2\frac{1}{2}$	$9\frac{1}{2} \times 2\frac{1}{2}$	4×2	

KINGPOST TRUSS

16. One of the simplest forms of trusses, called a **kingpost truss,** is shown in Fig. 18 (*a*), which illustrates a truss built entirely of wood. Here, *a* is the tie-beam, or chord ; *b*, *b*, the principal rafters ; *c*, the kingpost ; and *d*, *d*, the braces, or struts. The trusses are placed on, say, 10-foot centres, and the purlins *e*, *e* and the pole plates *f*, *f* run from truss to truss. On these purlins are placed the common rafters *g*, *g*, usually on 12-inch centres, while the ends of the tie-beam should rest on the stone templates *h*, *h*. At *i* is shown the ridge board, and at *j*, *j* the roof boarding. The scantling of timbers for such a truss varies with different builders, and also depends on the conditions under which the truss is built and on its proportion. For a rise of one-fourth of the span, which is about right for slates, the dimensions given in Table III will be found amply safe. The tie-beam may be made somewhat lighter than given if no ceiling is attached to it.

17. A detail of the kingpost is shown in Fig. 18 (*b*). The struts *d*, *d* are mortised into the foot of the kingpost *c* at *w*, *w*, and the principal rafters into the head at *k*, *k*. The ridge board *i* is housed into the head of the kingpost and the common rafters *g* are cut and nailed to it. The roof boarding is shown at *j* and the

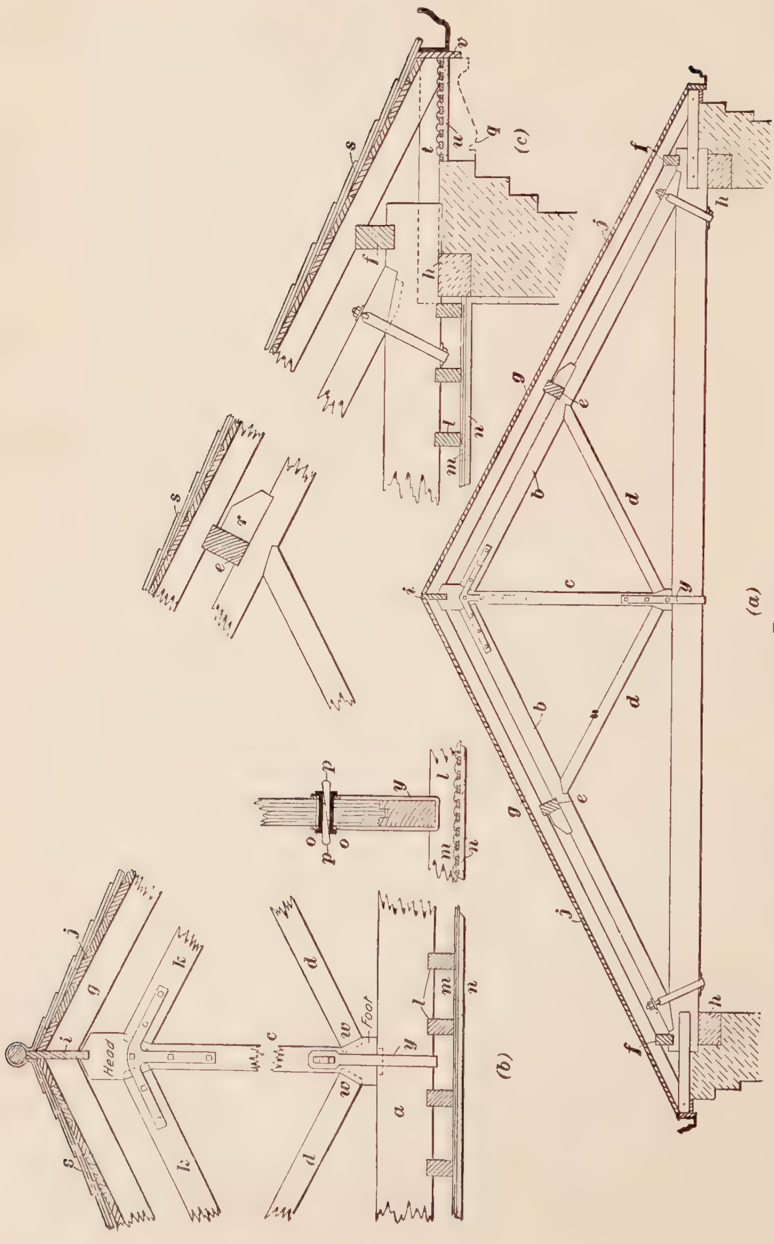


Fig. 18

slates at s. The ceiling joists l are notched to the under side of the tie-beam a and support the laths m and plaster n of the ceiling. The principal rafters are held in position at the head of the kingpost by an iron strap on each side; bolts passing through the straps and the wood securely hold the timbers

TABLE III

SCANTLING FOR KINGPOST TRUSS

Span Feet	Tie-Beam a Inches	King-post c Inches	Principal Rafters b Inches	Struts d Inches	Purlins e Inches	Common Rafters g Inches
20	$9\frac{1}{2} \times 4$	4×3	4×4	$3\frac{1}{2} \times 2$	$8 \times 4\frac{3}{4}$	$3\frac{1}{2} \times 2$
22	$9\frac{1}{2} \times 5$	5×3	5×3	$3\frac{3}{4} \times 2\frac{1}{4}$	$8\frac{1}{4} \times 5$	$3\frac{3}{4} \times 2$
24	$10\frac{1}{2} \times 5$	$5 \times 3\frac{1}{2}$	$5 \times 3\frac{1}{2}$	$4 \times 2\frac{1}{2}$	$8\frac{1}{2} \times 5$	4×2
26	$11\frac{1}{2} \times 5$	5×4	$5 \times 4\frac{1}{4}$	$4\frac{1}{4} \times 2\frac{1}{2}$	$8\frac{3}{4} \times 5$	$4\frac{1}{4} \times 2$
28	$11\frac{1}{2} \times 6$	6×4	$6 \times 3\frac{1}{2}$	$4\frac{1}{2} \times 2\frac{3}{4}$	$8\frac{3}{4} \times 5\frac{1}{4}$	$4\frac{1}{2} \times 2$
30	$12\frac{1}{2} \times 6$	$6 \times 4\frac{1}{2}$	6×4	$4\frac{3}{4} \times 3$	$9 \times 5\frac{1}{2}$	$4\frac{3}{4} \times 2$

together. The tie-beam is held to the kingpost by the iron strap y, the joint being made tight by two gibs o, o and two cotters p, p, which pass through the strap and the post. By driving in the wedge-shaped cotters, the connection can be made rigid.

18. In Fig. 18 (c) is shown the method of constructing the truss on the sides. At s are shown the slates, while the purlin e is held in place by the cleat r. Properly, the pole plate f should be placed directly over the template, but as in this particular instance such a position would be unfavourable and not on the tie-beam, the pole plate has been set a little farther out. The plancher piece t holds the soffit, or plancher u, which is here shown finished in lath and plaster, although it is often made of wood, and the fascia v is nailed to the end of the common rafter. In some cases the soffit is supported by consoles, as shown dotted at q, instead of the plancher piece t. The ceiling joists and lathing are shown at l and m, and the plaster at n.

QUEENPOST TRUSS

19. A **queenpost truss,** shown in Fig. 19 (*a*), is a good truss if the loads are evenly balanced ; as a rule, it is used for larger spans than the kingpost truss. The two queenposts are shown at *a*, *a* holding up the tie-beam *c* ; the straining beam is shown at *b*. At *e e* are shown the struts, resting on the foot of each queenpost and strutting up the principal rafters *d d* just where the weight of the purlin *f* is brought upon them. The common rafters *g g* are notched over the purlins *f f*. The size of timbers for a rise of one-fourth span is given in Table IV. These dimensions have been calculated for trusses 10 feet apart, but the

TABLE IV

SCANTLING FOR QUEENPOST TRUSS

Span Feet	Tie-Beam Inches	Queen-post *a* Inches	Principal Rafters *d* Inches	Straining Beams *b* Inches	Struts *e* Inches	Purlins *f* Inches	Common Rafters Inches
32	$10 \times 4\frac{1}{2}$	$4\frac{1}{2} \times 4$	$5 \times 4\frac{1}{2}$	$6\frac{3}{4} \times 4\frac{1}{2}$	$3\frac{3}{4} \times 2\frac{1}{4}$	$8 \times 4\frac{3}{4}$	$3\frac{1}{2} \times 2$
34	10×5	$5 \times 3\frac{1}{2}$	5×5	$6\frac{3}{4} \times 5$	$4 \times 2\frac{1}{2}$	$8\frac{1}{4} \times 5$	$3\frac{3}{4} \times 2$
36	$10\frac{1}{2} \times 5$	5×4	$5 \times 5\frac{3}{4}$	7×5	$4\frac{1}{4} \times 2\frac{1}{2}$	$8\frac{1}{2} \times 5$	4×2
38	10×6	$6 \times 3\frac{3}{4}$	6×6	$7\frac{1}{4} \times 6$	$4\frac{1}{2} \times 2\frac{1}{2}$	$8\frac{1}{2} \times 5$	4×2
40	11×6	6×4	6×6	8×6	$4\frac{1}{2} \times 2\frac{1}{2}$	$8\frac{3}{4} \times 5$	$4\frac{1}{4} \times 2$
42	$11\frac{1}{2} \times 6$	$6 \times 4\frac{1}{2}$	$6\frac{1}{4} \times 6$	$8\frac{1}{4} \times 6$	$4\frac{1}{2} \times 2\frac{3}{4}$	$8\frac{3}{4} \times 5\frac{1}{4}$	$4\frac{1}{2} \times 2$
44	12×6	6×5	$6\frac{1}{2} \times 6$	$8\frac{1}{2} \times 6$	4×3	9×5	$4\frac{3}{4} \times 2$
46	$12\frac{1}{2} \times 6$	$6 \times 5\frac{1}{2}$	7×6	9×6	$4\frac{3}{4} \times 3$	$9 \times 5\frac{1}{2}$	5×2

trusses may be placed at a greater distance. If no ceiling joists are used, the tie-beam may be made smaller. In (*b*) is shown a detail of the construction of the truss over the wall, which is practically the same as is followed in constructing the kingpost truss. Here, however, for variety, the gutter is shown closer to the wall, reducing the overhang of the roof. By this construction the plancher piece may be omitted, and the fascia *h*, which is nailed directly to the common rafter, made to support the soffit ; the other letters are as in view (*a*). In (*c*) is shown the detail of the head of the queenpost. Against this head rests the purlin *f*, while the cleat *j* helps to support

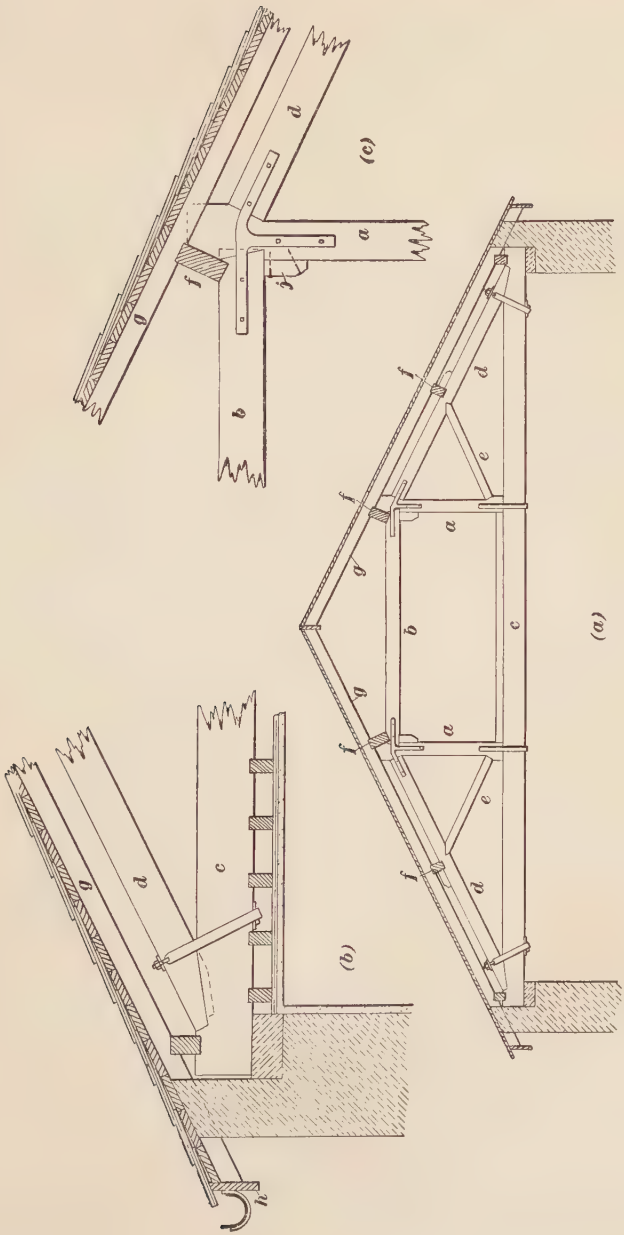


Fig. 19

the straining beam b; the other letters are as in (a) and (b). A wrought-iron strap is used on both sides of the timber, and through bolts hold the joint firmly in place.

RAFTER CUTS AND LENGTHS

20. Graphic Method.—The graphic method of obtaining the cuts and lengths of rafters shows that a roof is composed of a series of triangles that stand vertically or lie in an inclined position at a hip or valley line. In this method, the first step is to set out a roof plan to a large scale. The roof shown in

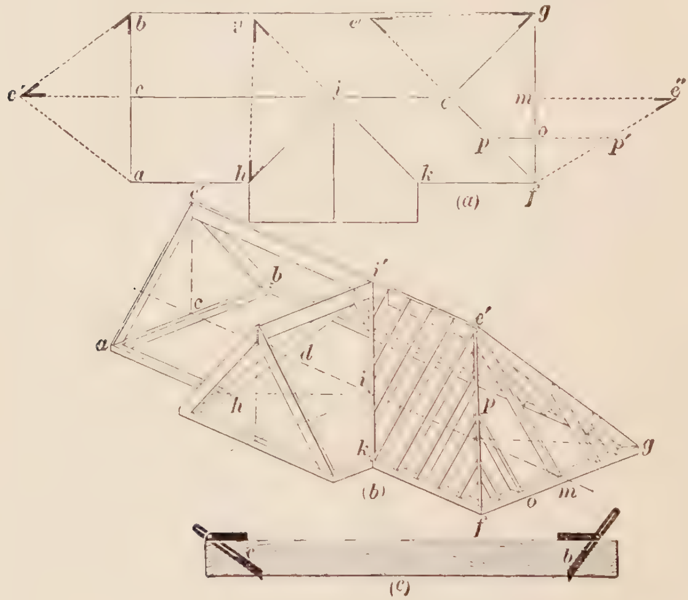


FIG. 20

Fig. 20 is of uniform pitch and has a wing the same width as the main building. One end of the roof is hipped, while the other ends are finished with gables, as may be readily understood by referring to the perspective view. In both the plan (a) and perspective view (b) the same letters refer to the same parts.

21. Length and Cuts of Common Rafters.—At the centre of $a\,b$, Fig. 20 (a), draw a perpendicular $c\,c'$ equal to the height

of the ridge above the wall plates; join c' and b. Then, the angle at b is the foot-cut, and that at c' the plumb-cut, of the common rafters; the length may be found by scaling. The angles are transferred to the rafter by means of a bevel, as shown in (c), in which b is the foot-cut, and c the plumb-cut.

22. Length and Cuts of Hip or Valley Rafters.—On the line that represents a hip on the plan, as $e\,g$, Fig. 20 (a), draw a perpendicular $e\,e'$ equal to the height $c\,c'$ of the ridge; join e' and g. Then, the angles at e' and g are the plumb- and foot-cuts, respectively, and the length may be found by scaling. The length and cuts for the valley rafter $i\,h$ in this case are the same as for the hip rafter, and are found in a similar way, as shown at h and i' in (a). Both hip and valley rafters have cheek cuts, which are the same as those of the rafters running from the wall plate to a hip and known as **jack-rafters.**

23. Length and Cuts of Jack-Rafters.—Draw a perpendicular $m\,e''$, Fig. 20 (a), at the centre of the span $f\,g$; with f as a centre and $e'\,g$, the true length of the hip rafter, as a radius, strike an arc cutting $m\,e''$ at e''; join f and e''; then, the angle at e'' is the cheek cut. The foot- and plumb-cuts will be the same as for the common rafters. The length of any jack-rafter, as $o\,p$, is found by prolonging it to cut $f\,e''$, as at p'; then, $o\,p'$, measured by scale, is the length of $o\,p$.

24. Cheek Cut for Rafters of Any Pitch.—On the face of the rafter draw the plumb-cut, as at $a\,b$, Fig. 21. Parallel with $a\,b$ draw $d\,e$ at a distance c equal to the thickness of the rafter; square over from d to f, and join f and a, thus obtaining the cheek cut.

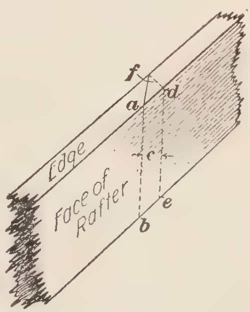


Fig. 21

25. Lengths of Hip or Valley Rafters; Wall Plates at Right Angles.—Having fixed the rise and run by the square for the common rafter, take 17 inches for the run of the hip or valley rafter. Thus, if the roof is one-third pitch, that is, 8 inches rise and 12 inches run, the hip or valley rafters will

have the same rise and 17 inches run. This rule gives results too great by about $\frac{5}{16}$ inch in 10 feet.

26. Lengths of Jack-Rafters.—Having obtained the lengths of the first two adjacent jack-rafters at the toe of the hip rafter by the graphic or other method, measure the difference between their lengths, and keep adding this difference for the subsequent ones.

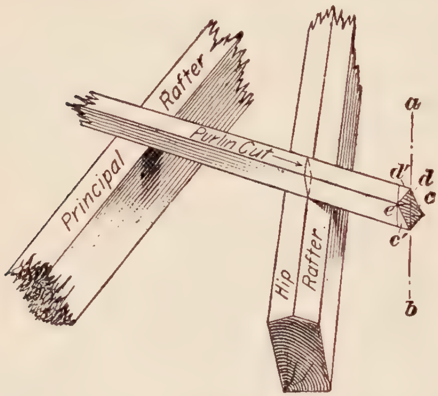


FIG. 22

27. Mitre Cuts for Purlins.—On the squared end of the purlin draw a plumb-line *a b*, Fig. 22. Then draw perpendiculars *c*, *d* to this line from the corners of the purlin. On the upper edge of the purlin set off a distance *d'* equal to *d*, and on the lower edge set off *c'* equal to *c* ; from *e* draw lines to the points marked, thus obtaining the lines for the cut. This is for a cut over a hip rafter ; where the cut is over a valley rafter, the bevel will be the same, but *d'* is set off on the lower, and *c'* on the upper, edge.

ROOFS OF SPECIAL FORM

28. Conical Roofs.—In Fig. 23 is a framing plan (*a*) and section (*b*) of a **conical roof**, the height of which is *c b* and the pitch *b a*. The rafters *a b* are notched over the plate in the same manner as though the roof were a plain gable, but the mitreing of the upper ends is somewhat different, and can be best understood by referring to the plan (*a*). The first pair of rafters *m*, *m* have a plumb-cut exactly the same as a gable rafter and are butted squarely together at *r*, while the second pair *y* are similarly cut and butted and spiked at their upper ends against the first pair. The rafters *z* are then cut the same as *y*, but with the

addition of a cheek cut at an angle of 45° on both sides of the upper end; and the rafters *x* are made similar to *z*, except that the cheek cuts are each $22\frac{1}{2}°$ instead of 45°. In the section (*b*) the rafters are shown overhanging the plate from *a* to *e* in order to form the eaves, so the length *e b* will be the length of the two rafters shown in the plan at *m*. From *b c* is then measured off, at right angles, the half-thickness of the rafter *m*, and through the point thus found a perpendicular line is drawn, cutting the rafter at *n l*; *e l* will then be the length of the rafters shown in the plan at *y*. The point *i*, where the edge of the rafter *z* intersects the edge of the rafter *y*, if projected down to the section (*b*), will cut the elevation of the rafter at *o j*, and *j e* will then be the length to the cheek cut of the rafters shown in the plan at *z*. The length of the rafters *x* to the cheek cut is found by projecting the points of intersection of adjacent sides of *x* and *y* to the top of the rafter in elevation, cutting the rafter at *p k*; *k e* will then be the length of the rafters to the cheek cut, as shown in the plan at *h*. The angle *e k p* will be the plumb-cut for all the rafters in the roof.

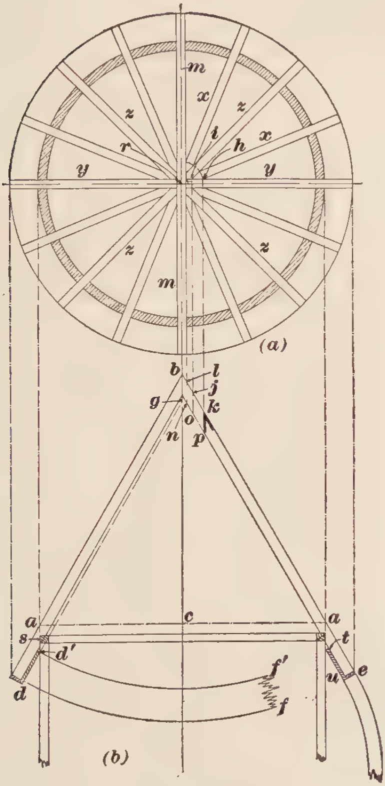


FIG. 23

29. The wall plate *s*, Fig. 23 (*b*), is made of two thicknesses of 2-inch plank cut long enough to receive the feet of four rafters. When set up, no two joints are in line perpendicularly. The

under side of the rafters projecting beyond the plate is sometimes lined, or sheathed, with a soffit board *t u*; in America this board is termed the *plancher*. The ends of the rafters at *e u* are then faced with a board called the *fascia*. The proper curvature of the edges of the soffit board *d f* is found by drawing the line *d g* parallel with the inside of the rafter and at a distance from it equal to the thickness of the soffit board; this line will intersect the axis *b c* of the roof at *g*. Then, with *g* as a centre and radii *g d* and *g d′*, describe the arcs *d f* and *d′ f′*, which will give the curvature required. The length of the soffit board on the line *d f* will, of course, be equal to the circumference of the roof at *d*.

30. Where a conical roof intersects the pitch of another roof, it is necessary to resort to particular framing in each case. Fig. 24 shows the plan of a conical-tower roof *a b c d* intersecting a flat single slope *e f h g*, the line of intersection being the curve *a d c*. In Fig. 25, the plan (*a*) of the tower is divided into sixteen equal parts by the radial lines *y′ a′*, *y′ x′*, *y′ b′*, etc., each of which represents the centre line of a rafter. The sectional elevation (*b*) shows the apex of the roof at *y* and the rafters and their slopes at *y b* and *y d*, while *d b* is the line of the plate. The rafter *v p* shows the slope of the main roof to which it belongs, and the point *w* shows the highest point in the line of intersection between the conical tower and the main roof. If the lines *y x*, *y t*, *y z*, etc., are drawn to points *x*, *t*, and *z*, the projections of the points *x′* in the plan, these lines will indicate the position of the tower

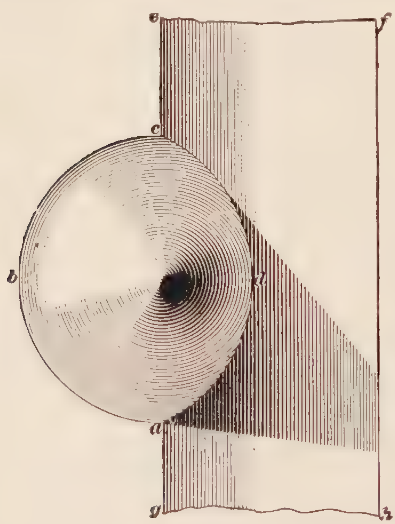


Fig. 24

rafters in the elevation; and where these lines intersect the main-roof slope at *s* will be points in the curved line of intersection between the two roofs. Projecting the points *s* on

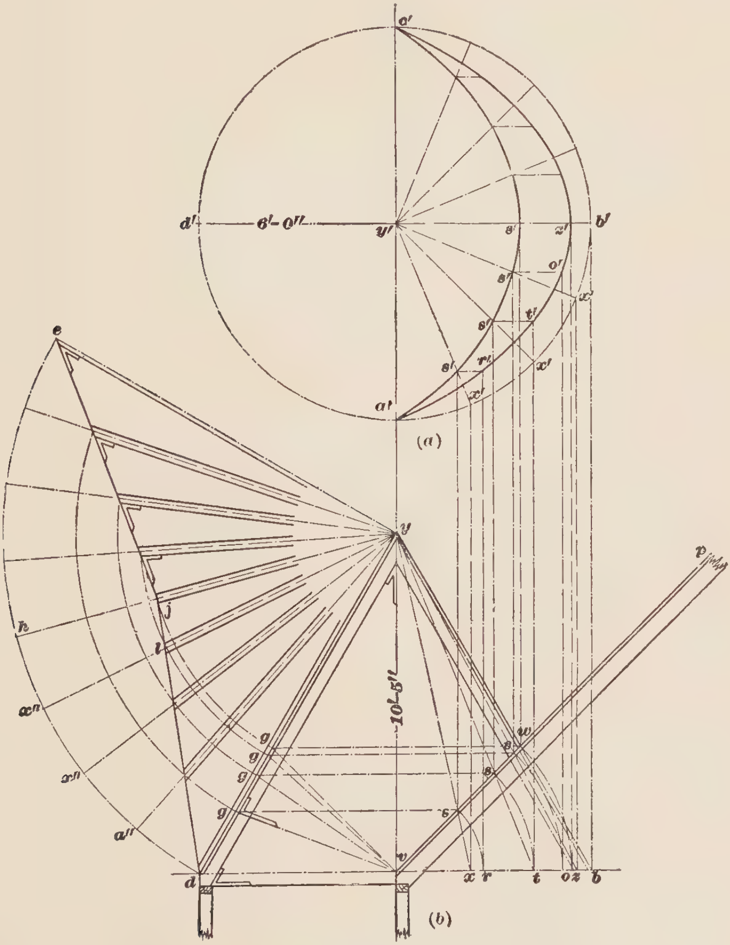


Fig. 25

each rafter to the plan of each rafter in (*a*) will give the points *s'*, which are all in the line of intersection between the two roofs, as shown at *a d c*, Fig. 24, and through which the line of intersection *a' s' c'*, Fig. 25, can be drawn. Horizontal lines

drawn from the points of intersection s to the outside of the rafter, or slope line, $y\,d$ will give the length $y\,g$ of each of the rafters $y\,s$.

31. The plumb-cuts at y, Fig. 25, and the foot-cuts at d are similar to those shown in Fig. 23, but the foot-cuts of the rafters, where they rest on the surface of the roof $v\,p$, are found in the following manner: With y as a centre and a radius $y\,d$, draw the arc $d\,h\,e$, on which space off the feet of the rafters, as at a'', x'', x'', etc., and to these points draw radial lines from y. Make $y\,j$ equal to $y\,w$ the length of the shortest rafter, and draw $j\,e$ and $j\,d$; then, the angle that $j\,e$ or $j\,d$ makes with the foot of each rafter will be the cheek cut of that rafter on the roof, and a line $g\,v$ drawn from the foot of each rafter $y\,g$ will give the angle $y\,g\,v$, which is the bevel of the foot-cut of each rafter as it rests on the roof $v\,p$.

32. The line of intersection between the two roofs, as shown in the elevation at $v\,w$, is seen in the plan, Fig. 25 (a), at $a'\,s'\,c'$, and, being at an inclination, does not exhibit the exact curvature as it would appear if seen in a horizontal position. The points in the line of the true curve may be found in the following manner: With v as a centre and with radii $v\,s$, describe the arcs $s\,r$, $s\,t$, $s\,o$, etc., and where these arcs intersect the line $d\,b$ draw the perpendiculars $r\,r'$, $t\,t'$, $o\,o'$, etc. From the points s' in the plan draw the horizontal lines $s'\,r'$, $s'\,t'$, $s'\,o'$, etc.; where these intersect the perpendiculars just described will be the points through which the true curve $a'\,r'\,t'\,o'\,z'\,c'$ may be described. The advantage of finding this curve is that from it a paper template may be made with the points $a'\,r'\,t'\,o'$, etc., marked on it. With this template, the curve may be marked out on the boards of the roof $v\,p$, and the rafters of the conical roof footed on the points $r'\,t'\,o'$, etc., with great exactness. Where the tower roof $d\,y\,b$ is of large size and is liable to throw considerable weight on the main roof $v\,p$, short pieces of timber should be framed in between each of a pair of rafters where one of the tower rafters is to set its foot. On small towers, the boarding of the roof is usually of sufficient strength in itself and requires no timbers inserted beneath it.

33. Hexagonal Roofs.—A **hexagonal roof** and the system of framing it are shown in plan in Fig. 26, where the six hip rafters radiate from the centre *o* to the corners of the hexagon *h f b g*, etc. The two pairs of rafters *c o j* and *g o h* should be set in place first, as in the conical tower, Fig. 23, and the other hip rafters are then fitted against them. To find the plumb-cut and foot-cut for the hip rafters, set off *o a* equal to the height of the roof and join *a* and *b*; then, the angle *o b a* is the bevel of the foot-cut, and the angle *o a b* the bevel of the plumb-cut, while the distance *a b* is the length of the hip rafter. The middle rafters *o j*, *o a*, *o c*, etc., are found by setting off the height of the roof at *o d* and joining *d* and *c*; then the angle *o c d* is the foot-cut and the angle *o d c* is the plumb-cut on the rafters *o j*, *o a*, *o c*, etc., and their length is equal to the distance *d c*. If, now, from *b*, *b e* is set off equal to *b a*, the length of the hip rafters, and the lines *e b* and *e f* are drawn, on each of which, as a centre line, the thickness of the rafter is set off, the jack-rafters *k x* and *l i* can be drawn in. Then, the angle *f x k* will be the bevel of the cheek cut, and the angle *o d c* will be the angle of the plumb-cut, which is similar to that of the rafter *o c*, to which the jack-rafters are parallel.

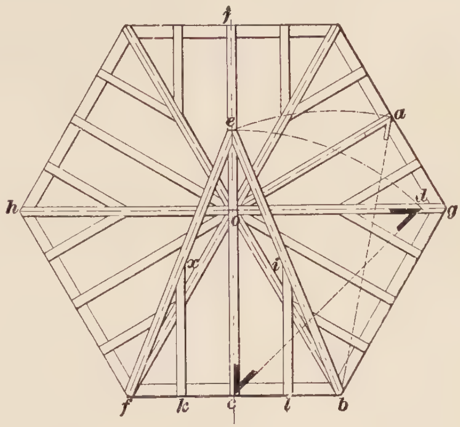


FIG. 26

34. Bell and Ogee Roofs.—Instead of the flat slope, the roof of a tower or other small structure sometimes has curved outlines, which are often compound in form; that is, one part is convex and the other concave. When this roof is put on a circular tower, it is called a **bell roof**, on account of its resemblance to the shape of a bell, but when applied to a square or polygonal

tower, it is called an **ogee roof**, because its outlines are of an *ogee*, or double-curved, shape.

35. In Fig. 27 is shown a plan (*a*) and a sectional elevation (*b*) of the ogee roof of a square tower. The ribs, or rafters, *a t* and *t b*, shown in the plan (*a*), are either sawn or bent to the required shape, fitted squarely together at the top, and fastened in place. The ribs at *f′ t* and *g′ t* are next fitted, but are each shorter in

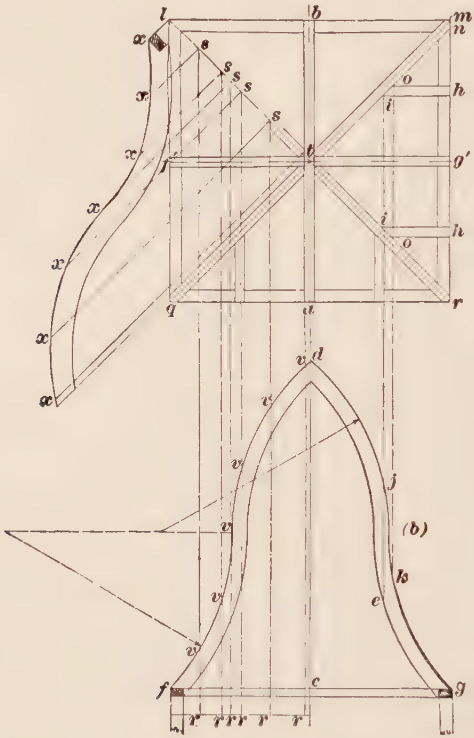


Fig. 27

length than the former pair by half the thickness of *a t* or *t b*. The hip ribs *l t*, *m t*, *r t*, and *q t* are then put in place, and finally the jack-rafters *o h*. To determine the length and curve of the hip ribs, or rafters, *l t*, *q t*, etc., draw *t x* at right angles to *l t* and equal in length, above *x* at the wall plate, to the height of the roof *c d*, as shown in the sectional elevation (*b*). Divide the rib *f d*

into any number of parts by making points as at *v*, and from these points draw lines *v s* parallel with *d c*. Where these lines intersect *l t*, draw the lines *s x* at right angles to *l t*, making *s x* in each case equal to the corresponding lines *r v* in the elevation (*b*). Through the points *x* draw the curve *x x x*, which will be the profile of the angle rib required.

36. The length of the jack-rafters *o h*, Fig. 27, is found by drawing the lines *o k* and *i j* from each side of their cheek cuts parallel with *c d* and intersecting *d g* at *k* and *j*. Then, *j g* will be the extreme length and proper curve of the jack-rafters, while their plumb-cut will be on the line *j e*. The cheek cut of these jack-rafters is found by drawing a line from *j*, which is on the outside of the rafter, to *k*, which is on the inside; it is shown in the plan (*a*) by the line *i o*. The hip rafters *l t*, *m t*, etc., must have their upper edges bevelled on each side of the centre line, as shown in the plan at *m n*. This is done in order that the boarding of the roof may have an even bearing on the angle rib. The edges of the boarding must meet accurately on the centre line of the rib *m t*. The amount of bevel will vary according to the pitch. The extent to which the rafter is cut away is determined by developing a line indicating the upper edge of the side of the rib, in a manner similar to that described for obtaining the curve *x x x*.

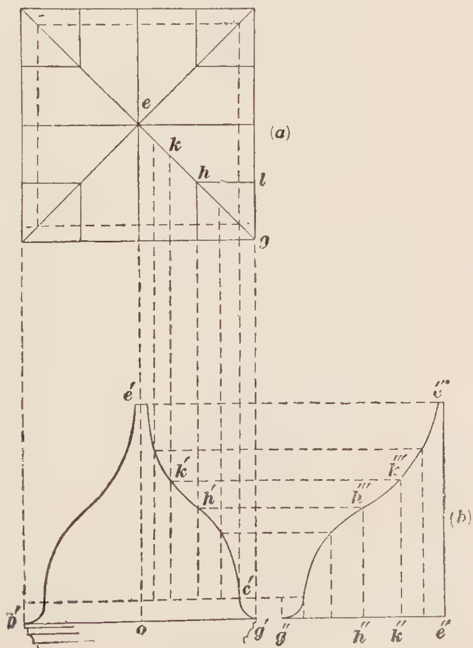


Fig. 28

37. Profiling Hip and Jack-Rafters for a Curvilinear Roof. In Fig. 28 (*a*) the arrangement of the rafters is shown in plan, $e\,g$ being a hip rafter and $h\,l$ a jack-rafter ; in Fig. 28, elevation (*b*), $b'\,g'$ is the span and $o\,e'$ the rise. To find the shape of the hip rafter $e\,g$, make $e''\,g''$ equal in length to $e\,g$, and set off $e''\,k''$, $k''\,h''$, etc., equal to $e\,k$, $k\,h$, etc. Draw perpendiculars at e'', k'', h'', etc. At e, k, h, etc., draw perpendiculars cutting the curve $e'\,g'$ at $k'\,h'$, etc. From e', k', h', etc., draw horizontals cutting perpendiculars from e'', k'', h'', etc., at the points e''', k''', h''', etc. A curve drawn through these points gives the required outline of the hip rafter. The shape of the jack-rafter $h\,l$ is the same as the curve $h'\,g'$.

DETAILS OF ROOF CONSTRUCTION

38. Cornice and Gutter.—In constructing the roof of a house, the rafters either terminate at the wall head and the eaves are finished with a cornice of stone or wood, or they are carried from 10 to 24 inches, or more, beyond the wall line, in order that the drip from the eaves may fall clear of the wall of the house, Fig. 29 shows methods of cutting the rafters where they so project. In view (*a*), the rafter *a* is notched over the wall plate *d* and continued to project beyond the wall line, the lower end of the rafter being shaped as shown to lighten the appearance. The tie *b*, which may also form the ceiling joist of the upper story, rests on the wall plate *d* and is spiked to the sides of the rafters on each side of the building. The projecting portions of the rafters are covered with $1\frac{1}{8}$-inch grooved and tongued boarding *f*, **V** jointed or beaded on the under side. The top edge of the rafters are checked at *c* to admit of the $\frac{3}{4}$-inch boarding *e* on the remainder of the roof finishing flush with the boarding on the projecting part. At the eaves, a triangular piece *h* is fixed to the upper surface of the $1\frac{1}{8}$-inch boarding to act as a tilting fillet for the slates or tiles *k*. The rain-water gutter is shown at *g*.

Another method of constructing the roof at the eaves is shown in (*b*). This example is similar to the other with the exception that the rafter *a* does not project beyond the wall line, the projection at the eaves being formed by means of a *sprocket piece c* nailed to the side of the rafter *a*. The sprocket piece is

checked at c to take the different thickness of boarding. At e and f is shown the boarding on the rafters and sprocket piece with the fillets over, about $1\frac{1}{2}$ inches by $\frac{1}{2}$ inch, fixed lengthwise across the boarding to give a fixing for the nails holding the slates or

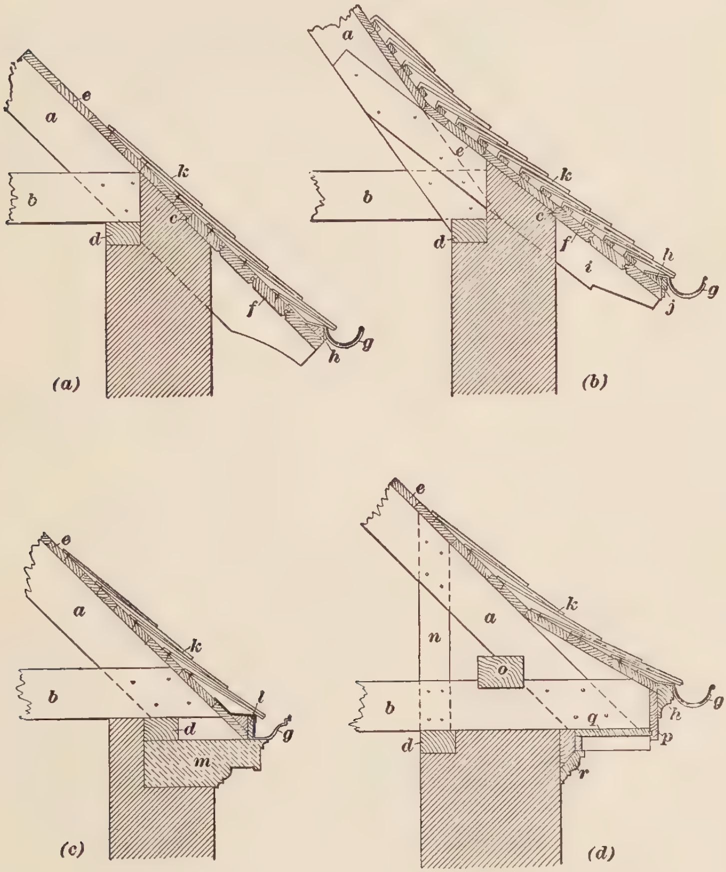


Fig. 29

tiles k. The tie is shown at b, the wall plate at d, the tilting fillet at h, the fascia board at j; and the gutter at g.

39. In Fig. 29 (c) is shown a section through the eaves of a building finished with a stone cornice m and having a moulded cast-iron gutter as top member. Here the rafters are shown at a,

the tie at *b*, the wall plate at *d*, the roof boarding at *e*, the slates at *k*, the fascia at *l*, and the gutter at *g*. A section through the eaves of a building finished with a wood cornice is shown in (*d*). The tie *b* is carried right through the thickness of the wall, is made to project, in order to serve as a bracketing for the cornice, and rests on the template *d*. Additional strength may be given to the framing of the timbers at the wall head by the introduction of the tie *n*. The rafters are shown at *a*, notched to the plate *o*, the roof boarding at *e*, the slates at *k*, and the gutter at *g*. At *h* is shown the moulded fascia fixed to the plain fascia board *p*, into which is tongued the soffit board *q* of the cornice, finished with the bed mould as shown at *r*.

DORMERS

40. **Dormers** are windows projecting from the roof of a building, and are framed out when the roof is constructed. The size and the shape of the openings left for them between the rafters depend on the size and the character of their roofs. Where the walls of a building are carried about half a story above the attic floor line, the upper portion of the dormer will project above the eaves line as shown in Fig. 30. In this manner very desirable rooms are obtained in the attic by reason of the extra wall height. The general appearance of the roof mass is also pleasing on account of the broken eaves line, and the effect of the lean-to roof over the dormer suggests that the roof has just been raised to accommodate the window. Such windows look best in roofs of high pitch, as the roof over the dormer will still have a reasonable pitch in itself. The eaves of the main roof in this case are shown finished with metal hanging gutters.

41. In Fig. 31 is shown a low, picturesque dormer, well adapted for cottage work; this dormer is perched on the slope of the main roof, the treatment of the roof being similar to that in Fig. 30. The sashes in this instance are *casement-hung*, which implies that they are hinged on the jambs and fold like a door. They are made to open either out or in, but are tighter when made to open out.

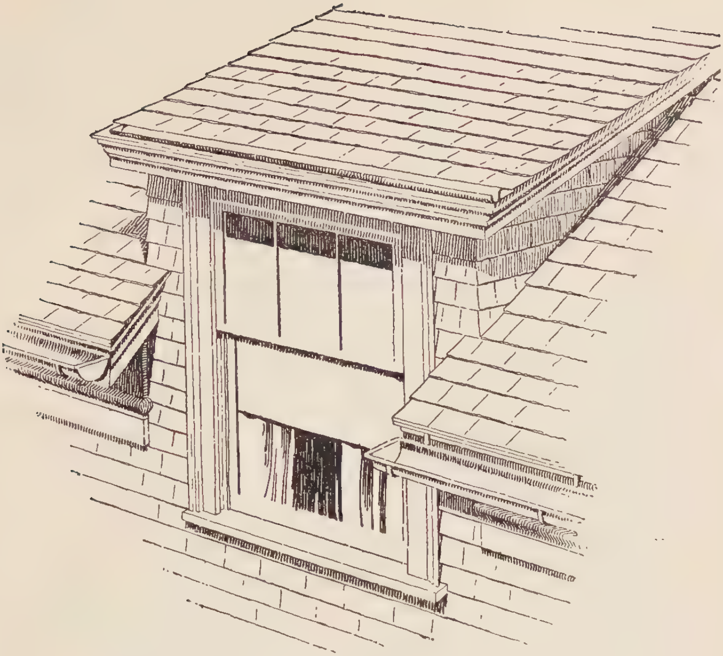


Fig. 30

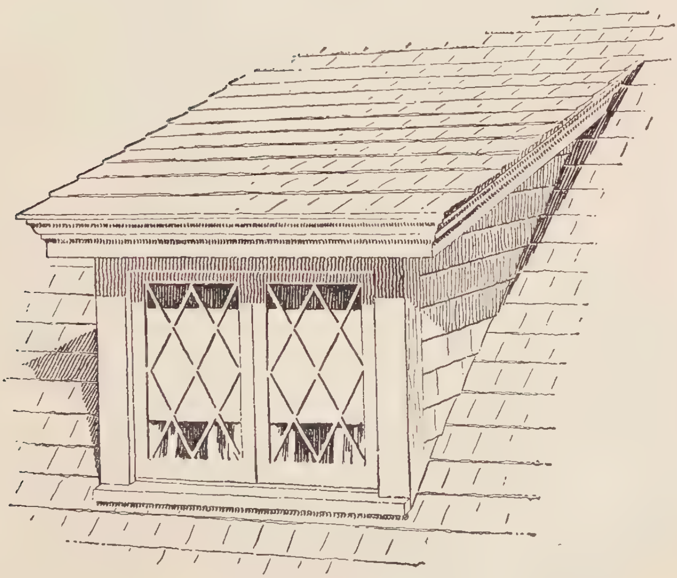


Fig. 31

42. Where a good width is desired in the interior of the room adjacent to the window, a portion of the wall may be continued beyond the window casing, as shown in Fig. 32. The eaves line of the dormer, which, in this example, would be somewhat long, is broken by a pediment, thus relieving the horizontal depression

FIG. 32

and giving the window the effect of greater height. The main roof is quite steep, suggestive of the pitch of a Mansard or gambrel roof, and thus a good pitch is obtained for the roof of the dormer proper.

43. Fig. 33 shows a dormer which is only as wide as the casing of the window frame. This dormer has a roof with a double pitch and a hip end and the cornice is carried round horizontally. This is a very desirable style of dormer, and when well proportioned and detailed always looks well. The

pitches of the front and sides should be the same as that of the main roof, unless the window is inserted in a Mansard or gambrel

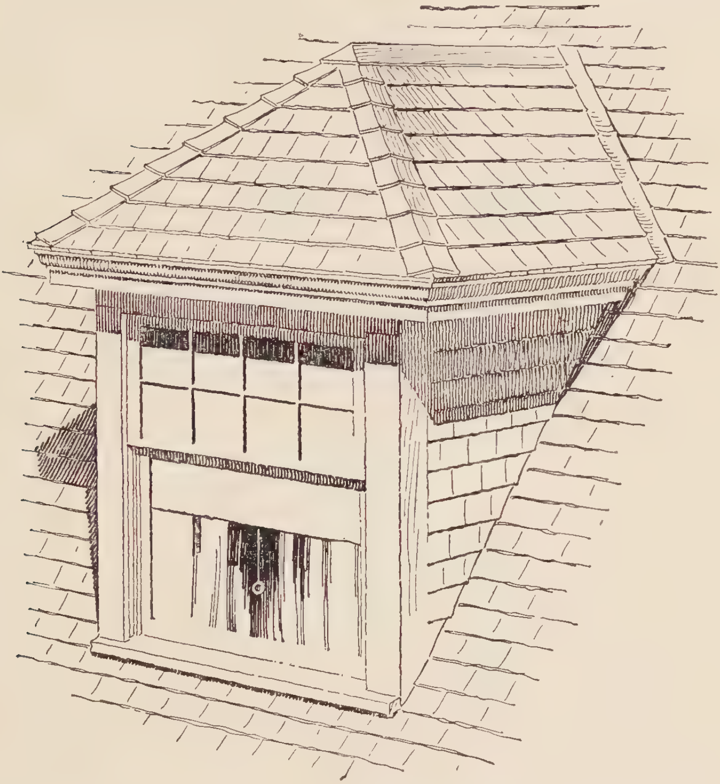


FIG. 33

roof, when the pitch should be made to suit the taste of the designer and the effect desired.

44. In Fig. 34 the dormer is finished with a pediment, and the corona, or fascia, is carried round horizontally. The cymatium, or crown mould, on the eaves is carried up the rake, thus making it continuous, but it has a somewhat different contour than the horizontal member, so that it may mitre properly at *a*, and is called a rake mould. Sometimes, the full cornice of the eaves is carried across the front with the

pediment surmounting it, but owing to the heavy overloaded appearance that it gives, the method is objectionable, and should never be followed. The pediment gives the dormer more prominence, and has a tendency to subordinate the main

Fig. 34

roof, unless it is very high. For cottage work, the hipped end gives a greater sense of repose to the roof and subordinates the dormer to the main roof, of which it is a part.

45. A dormer similar to Fig. 34 is shown in Fig. 35, but this is finished with what is called a *broken pediment*, in that the pitches of the cornice are broken and do not come together at the ridge, while the outline of the pediment is curved. Only a portion of the roof, equal to the thickness through of the pediment, would conform with the curve of the cornice, the roof

behind would be of a low pitch, falling behind the back of the pediment, as indicated by the dotted lines. The roof covering, owing to the flat pitch, would be of metal, either lead, zinc, or copper. The effect of such treatment of a pediment, while graceful and pleasing, and relieving the roof from the severe

FIG. 35

angular lines of the roof pitches, is condemned by many designers, in that it is constructed ornament and not ornamented construction. The form of the roof is not structurally suggestive of one designed to shed water, but rather to hold it, and in this sense violates good design. Others, however, prefer to violate this principle, on the ground that the good effect justifies it.

46. It will be observed that the foregoing examples of dormers have their *flanks*, or return walls, slated, tiled, or shingled. The construction of these walls is similar to that of the walls of a balloon-framed building. The junction of the flank and roof covering is laid close, the angle being made water-tight by concealed flashings laced in with each course of slates, tiles, or shingles, as the case may be, as will be described in *Roofing*.

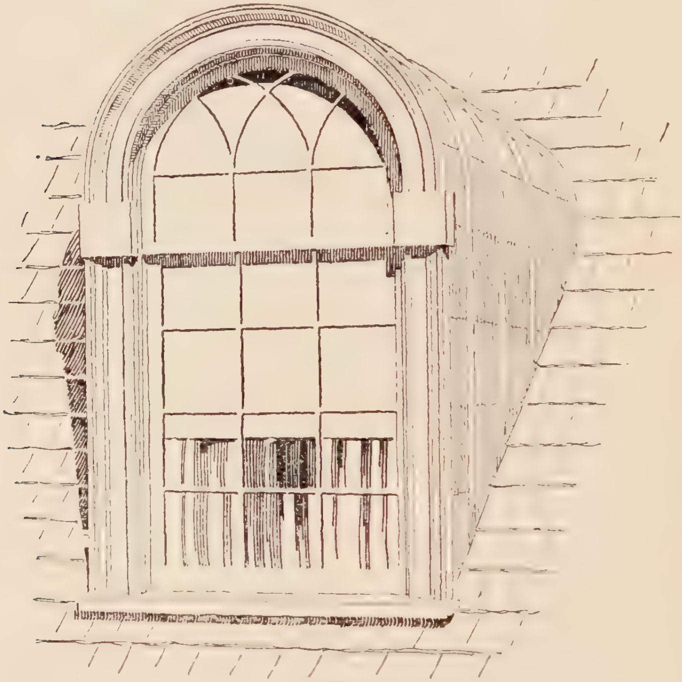


FIG. 36

The wagon-head dormer shown in Fig. 36 was much used in former times, and, unlike the previous example, is structurally correct in design. Owing, however, to the lack of an eaves line well defined by a cornice, and practically no frontal projection other than the curved architrave, this dormer lacks the sense of cover and protection which is the cardinal principle in well-studied roof design. As is obvious, the roof and flanks are covered with lead, zinc, or copper. Where judgment is

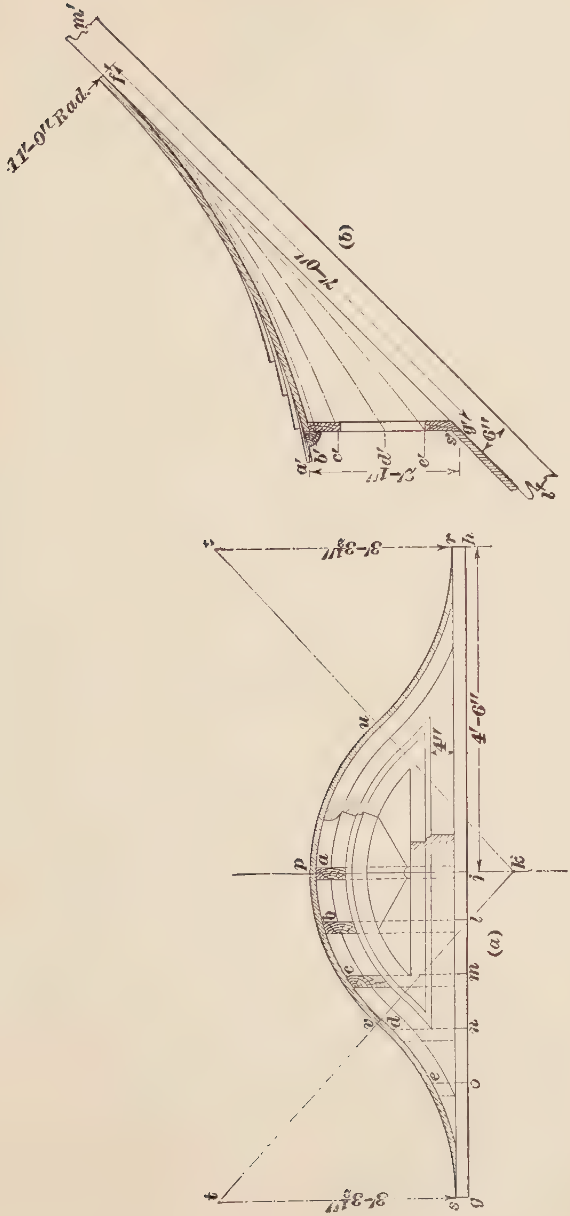


FIG. 37

used in placing this style of dormer in buildings, and when properly proportioned to the roof proper, favourable results in appearance are obtained. Complying with the fashion of former times, the sash bars are made twice as thick as usual, that is, from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in thickness, thus giving an increased body to the window as a whole.

47. Eyebrow Windows.—Sometimes, the roof openings are very small, and introduced as much for ornament, in breaking long stretches of roof, as for light or ventilation; this is particularly the case in the form known as the **eyebrow window,** shown in Fig. 37, in which (*a*) is a front elevation and (*b*) a section through the centre of the roof. The dotted lines b', c', d', etc., of this section show the curvature of each of the ribs b, c, d, etc., of the front elevation. The example shown in Fig. 37 is 9 feet in length from g to h, which is the top line of the main rafters, as shown at g' in (*b*), while $s\,r$ is the top line of the roof sheathing, as shown at s'. The height $j\,p$ is 2 feet, and the curve of the front elevation of the roof $s\,p\,r$ is formed with three arcs of circles, the centres t, t, k of which are located in the following manner: Prolong the centre line $p\,j$, and with some point k as a centre, describe the arc $u\,p\,v$ with such a radius that the points u, v, where this arc intersects the lines $p\,r$ and $p\,s$, will fall below p less than half the distance $p\,j$. Then, from k, draw the lines $k\,t$ through the points u and v, and the points t, t where these lines intersect $r\,t$ and $s\,t$, drawn perpendicular to $s\,r$, will be the centres for the arcs $u\,r$ and $v\,s$, which complete the compound curve of the top of the window. All the curved parts of the elevation are described from these centres, the arcs above the lines $k\,t$ being described from k as a centre, and those falling below the lines $k\,t$ being turned on t, t as centres. The ribs, or rafters, a, b, c, d, e, are now spaced off to stand at about 9 inches on centres, and the top and bottom edges will be bevelled to conform more closely to the curved outline of the roof, except the middle rib a, which is practically rectangular in section.

48. In the section through the centre of the window shown in Fig. 37 (*b*), a', b', c', d', and e' are the ends of the ribs shown at a, b, c, d, and e in the front elevation (*a*); and the lines $f'\,a'$,

$f' b'$, etc., are the tops of these ribs and the profiles of their curvatures. The rafter $l' m'$ shows the pitch of the main roof, and the roof of the eyebrow window curves upwards toward this rafter and becomes tangent at f'. All the ribs $a' f'$, $b' f'$, $c' f'$, etc., become tangent at f', and the bevels of their top and bottom sides, shown in the front elevation (a), gradually diminish as they recede, until they are all rectangular in section. The curvature of the ribs, as shown by the dotted lines $f' c'$, $f' d'$, etc., is determined by striking the curve of the uppermost rib with the arc of a circle, the radius of which must be perpendicular to the rafter $l' m'$ at f', and the distances $g' e'$, $g' d'$, $g' c'$, etc., are set off to correspond with $o\,e$, $n\,d$, $m\,c$, etc., in the front elevation. From each of the points e', d', c', etc., is then drawn the top line of the rib to f', varying the curvature in each successive rib to such a degree as will keep them the same relative distances below one another as at their starting points a', b', c'. etc. The ribs are sawn out of 2-inch plank on lines developed as just described, and the roof battens are bent over the curve and continued on the main roof without interruption, as the curved outline of the window removes all necessity of valleys, and, consequently, of flashing. When the roof is slated or tiled, the lines of the slates or tiles are carried along over the eyebrow window, so that, in reality, it forms simply a protuberance of the main roof.

49. Windows of the same general character as the eyebrow window are sometimes constructed with a flat square roof, curving upwards slightly as it recedes toward the main roof, so that its section is similar in shape to Fig. 37 (b). The ribs forming the roof construction, however, are all alike and rest on a straight plate in front, while the sides are slated, tiled, or sheathed in a similar manner to a dormer-window.

WOODEN SPIRE CONSTRUCTION

50. Angular Spires.—One of the most important points in construction is proper anchorage, and this requires special consideration in the case of a spire, owing to the high wind pressures to which a spire is subject. In Fig. 38 are shown

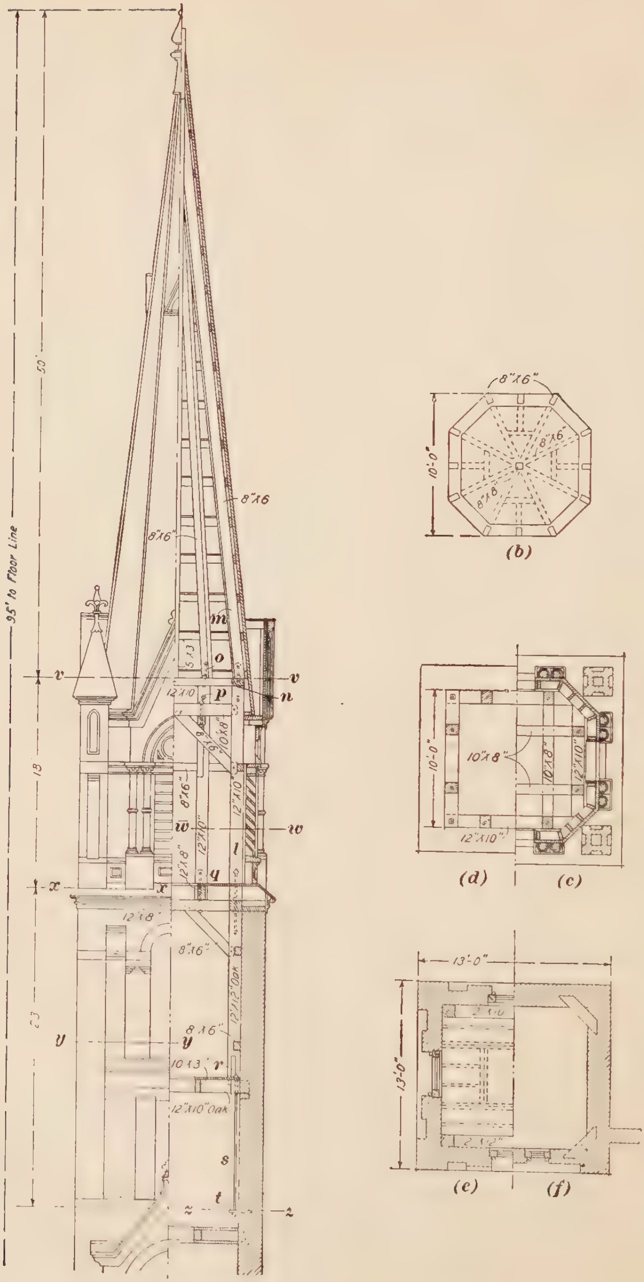

95' to Floor Line
50'
18
23
8"X6"
8"X6"
8"X8"
m
o
v
v
p
n
12"X10"
w
w
l
q
x
x
12"X8"
8"X6"
12"X12" Oak
8"X6"
y
y
10X13
r
12"X10" Oak
s
t
z
z
(a)
10'-0"
(b)
10'-0"
10"X8"
10"X8"
12"X10"
12"X10"
(d)
(c)
13'-0"
13'-0"
(e)
(f)

FIG. 38

the framing and anchorage of an octagonal wooden spire. While the long, tilted rafters, usually spliced to attain extreme heights, are in compression on one side, they are in tension on the other. This is due to horizontal wind pressure, which has a tendency to tip over or raise one side of the base, with an opposite side acting as a fulcrum. To obviate this, the rafters *m*, Fig. 38 (*a*), are bolted to the plate *n*, which in turn is bolted to vertical timbers *l* in the eight internal angles of the walls. These timbers rest on and are strapped to the girders at *r* and are bolted at *s* to iron plates *t*, which are embedded in the walls below. This arrangement, together with its intermediate bracing, would make it necessary to dislodge two stories of walling before the spire would give way. Fig. 38 (*b*) shows a plan at the plate line taken through *v v* in (*a*) ; (*c*) shows a half plan at *w w* ; (*d*) is taken at *x x* ; (*e*), at *y y* ; and (*f*), at *z z*. The bolts *o* are 1 inch in diameter ; *p*, $1\frac{1}{4}$ inches ; *q*, $1\frac{1}{2}$ inches ; and *s*, $1\frac{3}{4}$ inches. Although many other forms of construction are in use, they are all based on the same general principles as here given.

51. Conical Spires.—Prominent features of city and suburban architecture are presented in the circular towers and the semi-circular bay windows finished above the main roof as towers. The wall angles of public buildings are often ornamented with small towers terminating in spires, which form a pleasing characteristic in the design. It is to be regretted, however, that want of study and lack of attention to detail cause the roofs of many of these towers to have the appearance of candle extinguishers.

The elements requiring consideration are the proper proportion of height to diameter, the relative value of the tower roof to the main roof, and the placing of the rafters with due reference to the eaves line. The unevenness of the finished roof is another defect, and is usually produced by using boarding of too great width. This causes the vertical lines, where the boards abut, to be visible after the slating or tiling has been applied. This fault is somewhat obscured by using tiles that present only vertical rolls placed at close intervals.

The width of the boarding should be so regulated that the arc included between the edges of the boards will be, as near as practicable, a straight line. If the bell cast is such that extra-thick material is required to secure the desired curvature, the staves may be made up of two or more pieces in the length. Conical roofs with a bell cast at the eaves are characteristic of French architecture. The tower roofs of the Château Martinville, the Château de Vitre, and the Château Chenonceaux are striking examples They are, whether by accident or design, very successful, being graceful in outline, and with a smooth and continuous surface.

The trades, as a rule, use the method whereby the work can be executed with the least amount of material and with the greatest despatch, without giving a thought as to the durability and ultimate effect. This is especially so where the work is sublet and where each contractor considers himself independent of the others. Thus the task of covering up and trying to improve the poor work of a predecessor generally devolves on a trade foreign to the necessities of the case.

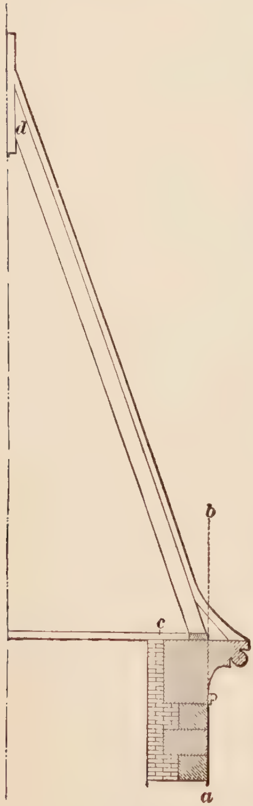


Fig. 30

52. A fixed rule for the height of tower roofs would not be desirable, as the opinions of designers vary, but a safe course to follow is to have a low-pitched tower roof when the main roof is low, and to have a steeper one when the main roof has a greater pitch, thereby producing a feeling of unity in the design. A rational rule to follow in placing the rafters is to continue the constructive lines, and never let the toe of the rafter project beyond the plate line, or face, of the tower wall. When the cornice is in position

the space between the crown moulding and the toes of the rafters may be utilized for a gutter, or preferably a *bell cast*, flare, or curved continuation of the roof slope. In Fig. 39 is shown the proper position of the rafters, *a b* representing the wall line, *c* the wall plate, and *c d* the roof rafter, so set that the toe is on the line *a b*.

53. To obtain the proper horizontal and vertical mitreing for the curved boarding, when the pitch of the roof and the

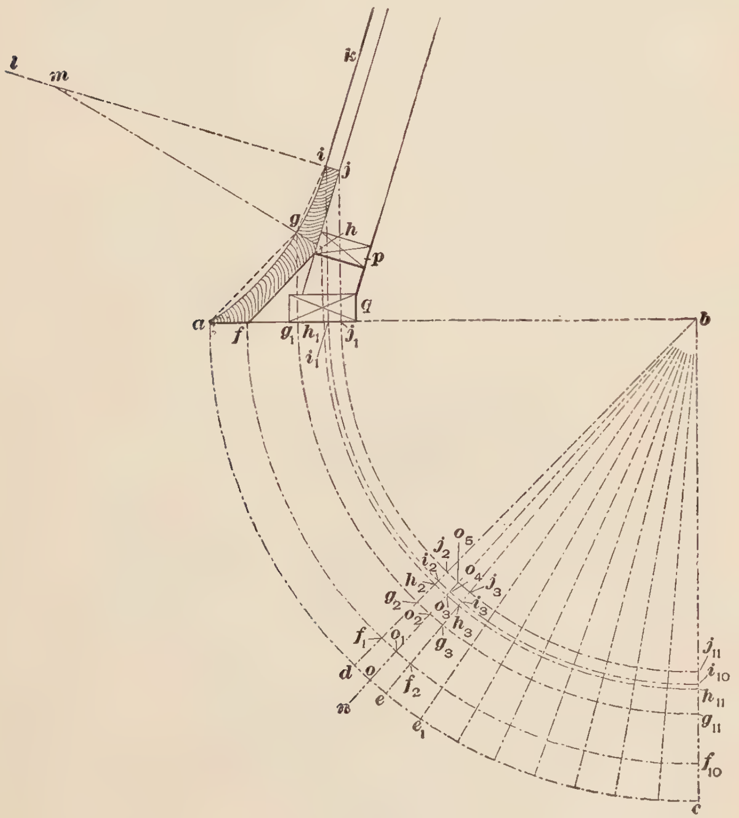


Fig. 40

curve of the bell cast are given, the following method may be used: Set out one-quarter of the plan of the tower, as in Fig. 40,

as indicated by the quadrant $a\,b\,c$; at d, divide the arc $a\,c$ into two equal parts, and draw $b\,d$; divide the arc $d\,c$ into any desired number of spaces, as indicated at $e\,e_1$, etc., denoting the width of the boarding, or staves, at their base. The surfaces contained in $a\,f\,g\,h$ and $g\,h\,i\,j$, with a face width equal to $d\,e$, represent the smallest material out of which the staves may be cut. At the junction of the straight slope of the roof $i\,k$ and the bell cast $a\,g\,i$, draw the line $i\,l$ at right angles to $i\,k$, and, as the arc $a\,i$ is tangent to $i\,k$, the upper mitre cut will be the extension of $i\,l$ at j. On the line $i\,l$, at the given point of radius m, describe the arc $a\,i$. Divide the arc $a\,i$, as at g; from the centre m draw the line $m\,h$ through the point g; then, $g\,h$ will be the horizontal mitre cut for the foot of the stave $g\,h\,i\,j$, and the upper horizontal mitre cut for the stave $a\,f\,g\,h$. To obtain the vertical-side mitre cuts, project the points g, h, i, and j to the horizontal line a, b, cutting it at the points g_1, h_1, i_1, and j_1. With b as a centre, describe the quadrants $f\,f_{10}$, $g_1\,g_{11}$, $h_1\,h_{11}$, $i_1\,i_{10}$, and $j_1\,j_{11}$. From b draw the line $b\,n$ through the centre of a stave, as at o.

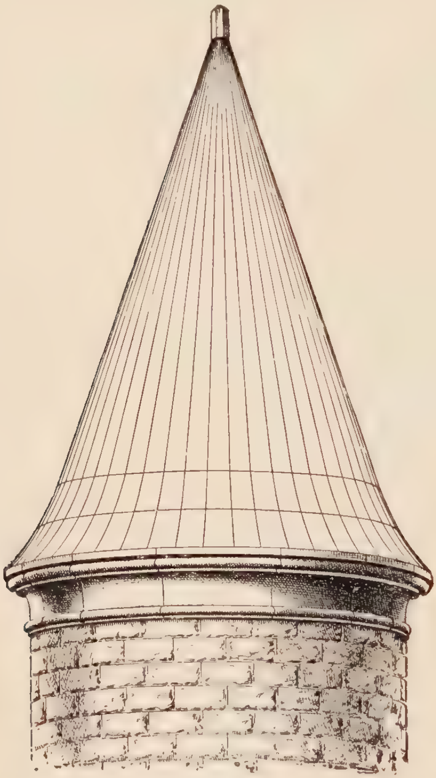


Fig. 41

54. In setting out the stave, set off on the face of the lower one, at its base, the ordinates $o\,d$, $o\,e$, and at its top the

ordinates $o_2\, g_2$, $o_2\, g_3$. Set off on the under side of the stave, at its base, the ordinates $o_1\, f_1$, $o_1\, f_2$, and at its head the ordinates $o_2\, h_2$, $o_3\, h_3$. Then $b\, d$, passing through $f_1\, g_2\, h_2$, and $b\, e$, passing through $f_2\, g_3\, h_2$, give the vertical side mitre cuts of the lower stave. Set off on the face of the upper stave, at its base, the ordinates $o_2\, g_2$, $o_2\, g_3$, and at its head the ordinates $o_4\, i_2$, $o_4\, i_3$. Set off on the under side of the stave, at its base, the ordinates $o_3\, h_2$, $o_3\, h_3$, and at its head the ordinates $o_5\, j_2$, $o_5\, j_3$. Then $b\, d$, passing through $g_2\, h_2\, i_2\, j_2$ and $b\, e$, passing through $g_3\, h_3\, i_3\, j_3$, give the vertical side mitre cuts of the lower stave. At h is shown the joint between the two vertical sections of the staves, where a purlin p is placed, to which the ends may be attached. At q is the section of the circular wall plate, on which rest the rafters. Where the towers are lofty, it will be found necessary to secure the wall plate q to the stone cornice by means of expansion bolts, so that they will be prevented from tilting under wind pressure. Fig. 41 shows a perspective sketch of a conical roof with a bell cast at the eaves ; also the method of sheathing or boarding as it would appear preparatory to receiving the final covering.

BALLOON-FRAME CONSTRUCTION

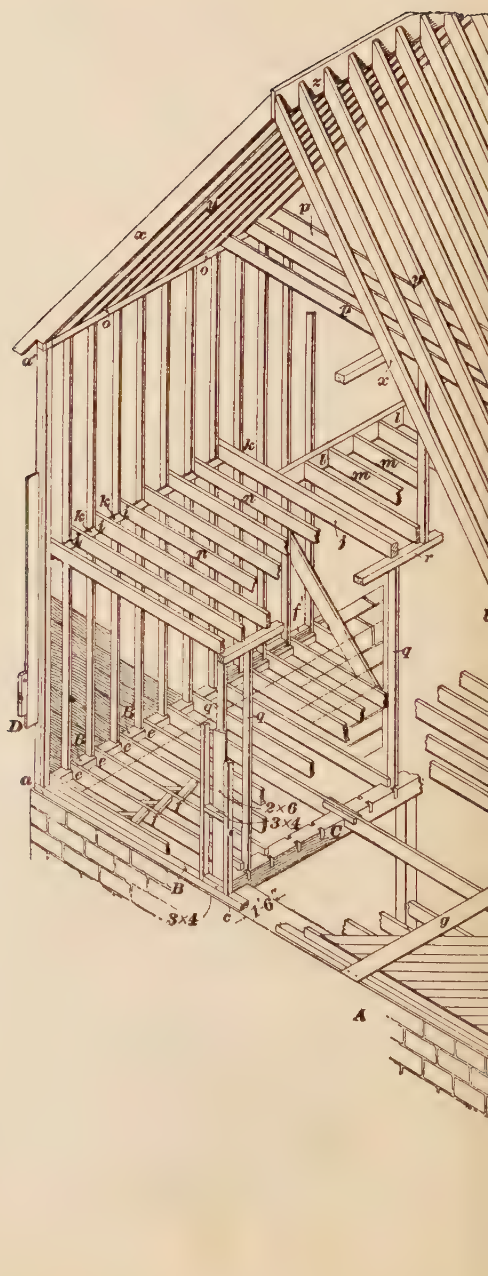
GENERAL DETAILS

55. Balloon framing is the term given to that system of construction much used in America and the Colonies, but not used to any great extent in the British Isles, in which the skeleton, or framework, of a building is spiked together with butt joints, and depends almost entirely for its strength and stability on its exterior covering and the manner in which this covering is applied. The construction is here described to show the methods of building construction employed in other parts of the world. Such methods and means as have already been set forth will be applied, and such new or additional features as the necessity or the economy of the construction demands will be considered as they appear.

56. In Fig. 42, *A* is a stone foundation wall, 1 foot 6 inches in thickness. On top of the foundation wall, the sill *B* is laid and well bedded by repeated blows from a heavy hammer in a bed of lime mortar *c*. The outside edge of the sill, which is kept back 1 inch from the face of the wall, is then *pointed up*; that is, the joint between the sill and the top of the wall is carefully scraped off to give it a neat, even finish, and any surplus mortar is removed from the 1-inch projection of wall. The plate is halved and spiked at the corners as shown at *a* and *b*, and where the pieces composing it cannot be obtained in sufficient lengths, the sill is pieced out by means of the bevelled halved or splice joint, as shown at *d*. In exposed situations where high winds are frequent, it is not uncommon to anchor the sill to the wall by means of anchor bolts, which are from 1 inch to $1\frac{1}{2}$ inches in diameter, and are firmly built into the masonry of the wall with the thread end projecting above it. Holes are then bored into the sill to fit over these projecting ends, and, after the sill is laid and levelled, it is secured in place by screwing nuts on the ends of the bolts with a washer between each nut and the sill.

57. After the sill is set in its place, levelled, and its angles squared so as to be absolutely true, the first tier of floor joists may be laid. These floor joists are notched over the sill to bring their tops to a level line; or, where great economy of material is to be desired, the joists are notched 4 inches or more to bring their under sides about flush with the bottom of the sill, where they are bedded in the same mortar topping of the foundation as the sill itself, or the beams are blocked up on top of the wall with pieces of slate. But in all cases where they are so deeply notched the floor joists must have a solid bearing on the wall, as shown at *e*, Fig. 42.

Where the span is so great that the joists must have an intermediate support, a brick wall or a girder *C* supported on posts is carried through the centre of the house. A brick wall is better than a girder, for, when built up to the same height as the foundation walls and capped with a wooden sill of the same thickness as the main sill, there will be the same amount of



2×6
3×4
3×4
1'6"

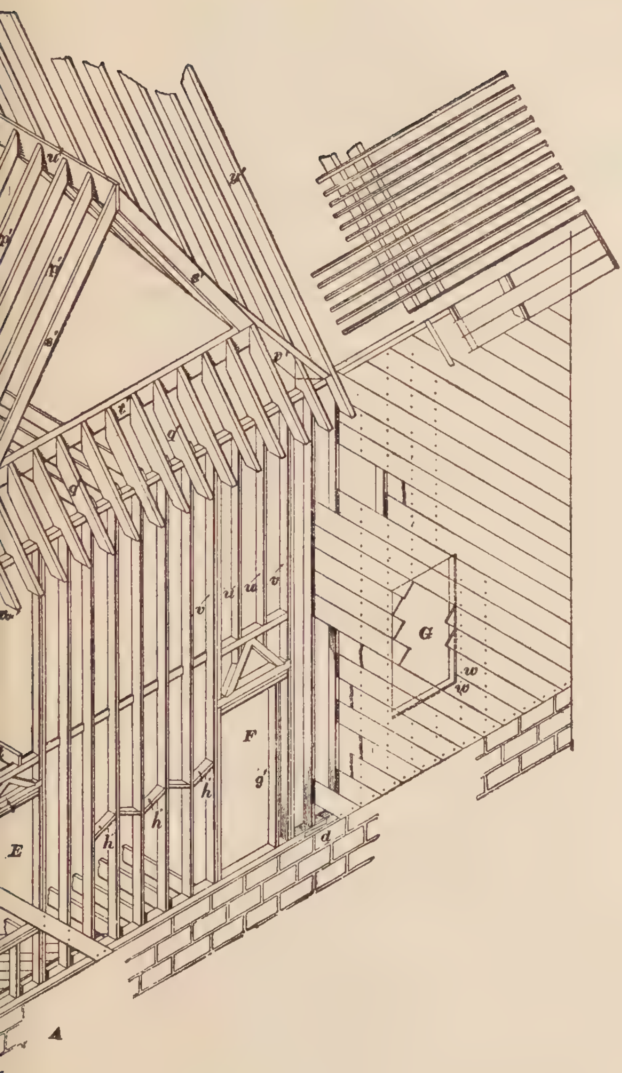


Fig. 42

shrinkable material in all the supports of the ground-floor joists and partitions. Where a girder is used, however, precautions must be taken to equalize, as nearly as possible, the effect of its shrinkage with that of the main sill. This is done by notching the girder, as shown, and by notching the joists in the same manner as at the sill, so that the solid portion of the girder below the notches is equal in thickness to the depth of the main sill of the house.

58. Great care is required in cutting these joints, so as to ensure a good seat, not only for the joist or beam on the bottom of the notch, but also for the projecting tenon of the joist on the top of the girder. Too much weight on the notch will tend to split the girder, while too great a strain on the tenon will tend to split the joist. For this reason, in strictly first-class work, the joists are simply sized over the main sill, and their inner ends are similarly sized over an interior sill supported on a brick or stone wall. Whether they meet on a girder or wall, the ends of the joists should be butted together and held by cleats nailed on each side; they should never be lapped one joist on the side of the other and spiked together, as this produces irregularity in the joist spacing, and makes the subsequent fixing of pipes, etc., very troublesome. The floor joists, having been spaced and securely nailed along sill and girder at the uniform distance of about 12 or 16 inches on centres, are then cross-bridged, as shown at *f*, Fig. 42.

59. When the floor joists are being bridged, or even before it is commenced, the side walls of the building are started by setting in position the corner posts *a a′* and *b b′*, Fig. 42. After these posts have been carefully plumbed with a level and straight-edge, as shown at *D*, or preferably by a long plumb-rule and plumb-bob, they are braced in position by two pieces of sheathing *g* nailed securely to the posts and to the sill. The corner posts are generally composed of two pieces spiked together, as shown at *b b′*, and the larger piece is sometimes, though not always, mortised or dowelled into the sill.

60. After the corner posts are secured, the studs are spaced along the sill 12 or 16 inches on centres and are spiked both to

the sill and to the floor joists. These studs are then plumbed and carefully alined along the outside edge of the sill, and secured in place with braces similar to those of the corner post, those on the exterior being permanent in the form of sheathing, while the brace extending from the side of the stud to the floor joist is only a temporary affair, to be removed as soon as the interior partitions and the first-floor joists are in place. The studs and corner posts are all cut to an even length before they are set in place, and at the same time the notches for the ledger boards *k*, Fig. 42, are cut in the studs 4 inches wide and 1 inch deep. As soon as the studs are set in place, the ledger board itself is fitted and spiked to each stud with two nails. On this ledger board, the first-floor joists *n* are laid, each joist being slightly notched on its under side, as at *i*, in order to bring the tops of the joists to an even alinement. The first-floor joists are not nailed to the ledger board, but are securely spiked to each stud, on the same side of the stud as the joists in the tier below.

61. The joist shown at *j*, Fig. 42, is double the thickness of those at *n*, as it is a trimming joist and carries the trimmer *l* and the weight from the floor joists *m*. This trimmer and trimming joist form one end of the staircase well, or opening, and if there is to be a similar opening in the second, or attic, floor, great care must be taken to place the attic-floor trimmer perfectly parallel with and plumb over this one, as trouble will arise when the stairs are built unless such care is observed.

62. As soon as the first-floor joists are laid, the tier above may be started, but if this third tier is simply to consist of ceiling joists, and the attic story is not to be finished off in rooms like the rest of the house, the wall plate *o*, Fig. 42, should be laid first. This plate is usually composed of two pieces of studding nailed together and so lapped that the joints of any two lengths are as far apart as possible, and is laid along the top of the wall and securely nailed to each stud. The attic joists are then notched over the plate as the ground-floor joists were notched on the sill, and then securely nailed in place.

The exterior frame is now fairly complete from sill to plate. While the work just described was in progress, the partitions

were erected, the first, or rough, floors laid on the interior, and the window and door openings framed and the frame sheathed on the exterior. In fact, it is sometimes necessary to erect the main partitions at the same time as the outside walls, in order to provide a support for the interior ends of the floor joists.

63. The studs *q*, *q*, Fig. 42, supporting the partition plate *r* show the position of a principal partition supporting the ends of the first-floor joists *m* and *n*, and the continuation of this partition in the first floor supports the interior ends of the attic joists or tie-beams *p*. The plate *r* on the top of these stud partitions, like the main wall plate *o*, is generally composed of two pieces of studding nailed together, and though one thickness would be strong enough for all practical purposes, the two pieces are preferable in order to secure the same amount of shrinkable material under each end of the joist; and, as the ledger boards on the outside are 4 inches deep, the plate in the interior is also made 4 inches deep.

64. The framing of the openings is shown at *E*, Fig. 42, where the studs on each side of the opening are doubled and spiked securely together to act as practically one piece. The head and the sill of the opening, if it is a window, are also composed of doubled studs, and where the window is over 3 feet in width, the top should be trussed. The double studs at the sides of the opening are carried through to the plate, and if there are to be two openings, one over the other, it is simply necessary to truss the upper one, unless there are floor joists or other details that will concentrate too much weight over the lower opening. This is the case at *E*, and the window head is trussed to carry the load of the two joists *t* to the double studs at the sides.

65. In setting out the studding of the exterior walls of a building, two methods are used. In one, the double studs at the sides of the doors or windows are first placed in position, and the single intermediate studs are spaced 12 or 16 inches from centre to centre between them. In the other method the studs are spaced throughout at the uniform distance of 12 or

16 inches on centres, after which the door and window openings are sawn out and the studding framed to suit. The former of these methods is shown at *E*, Fig. 42, and the latter at *F*, where two studs *u* have been cut out and the adjacent ones *v* have been doubled, the space between them being trussed to carry the floor joists in the same manner as at *E*. This leaves an opening of 4 feet between the centres of the studs at the sides of the opening, and, as this is more than is required, the opening is limited by the stud *g′* cut in between the truss and the sill; or, if the plan requires the door to be further to the right, two studs can be cut in and the opening centred at any point desired.

66. Sheathing is composed of $\frac{7}{8}$-inch boards, matched or unmatched, and planed on one side to give them a uniform thickness. In balloon-frame buildings the sheathing should always be laid diagonally, as it is on the bracing effect of the diagonal sheathing that the building depends for its strength. The sheathing is then carried over the whole side of the building, no attention being paid to door or window openings. Where a sheathing board projects a few inches over an opening, it is permitted to remain so, and the next board to it in the course is started from the other side of the window. This arrangement is illustrated at *G*, Fig. 42, where the dotted lines show the outlines of the window opening, and the full lines indicate the sheathing boards as they are laid up on the studs, to each one of which they are nailed with two nails. At *w* is shown the sheathing sawn out to the opening, the boards being cut flush with the face of the studs.

67. Roofing.—When the sheathing is nearly completed and the first, or rough, floors are laid, the structure is ready to receive the first timbers of the roof. The pitch of the roof in this case is rather steep, being 17 inches rise to 12 inches run. The plumb-cut of the rafters will be found as before described. The foot-cut and overhang for the eaves are measured and cut, and when one rafter is finished and sawn complete, it is used as a template for marking and cutting all the others, before the framing of the roof is commenced.

The first rafters set are those forming the end of the gable at x, Fig. 42. The ridge plate z is composed of a wide piece of $1\frac{1}{8}$-inch material bevelled on its upper edge, as previously explained. To this ridge plate the rafters x are spiked on opposite sides, and somewhere near the other end two other rafters are similarly spiked to hold the ridge in position. The rafters y and y' are so placed as to foot on the plate o adjacent to the valley rafters w' and v', which are then placed in position, having been previously cut to the required lengths. The valley rafter w' is first set, and then the valley rafter v' is securely footed on the plate and spiked against it. The trimmer plate t' is then spiked between these two valleys at the point where the slope of the smaller gable is to start, and after t' is securely nailed to the two valley rafters, the first two of the small gable rafters s' may be set in position, securely nailed to the trimmer plate t', and spiked through the ridge plate u', the other end of which is nailed into the angle formed between the two valley rafters w' and v'.

68. The ridge plates z and u', Fig. 42, and the trimmer rafter t' must, of course, be perfectly true and level, and when set they must be so securely fastened that subsequent operations will not force them out of line. The jack-rafters r' and p' may now be set in pairs, one each side of the valley rafter w'. This is done in order that the thrust may be the same on each side of the rafter at the same time, for, if all the jack-rafters were laid on one side at the same time, it would cause the valley rafter to bulge and curve out of line and prevent the opposite rafters from fitting properly. For this same reason great care must be exercised in setting the jack-rafters q', as, in driving them close into their places, the trimmer rafter t' is liable to be bulged inwards and out of line with the gable rafters s' above.

69. After all the rafters are in place, the boarding of the eaves is laid, as shown in Fig. 42, and above this boarding the shingle laths are laid, with a clear space between them equal to the exposed length of the shingles. The spacing of the shingle laths s is measured from the lower edge of the lowest roof board at the eaves, and the spaces are measured off up the rafters to the ridge, where any difference in exposure of

shingles can be taken up either by increasing or by slightly diminishing the width of the ridge boards when they are laid. Side sheathing, roof sheathing, and shingle laths must be nailed to each stud, or rafter, using two nails for boards and one nail for shingle laths. Where a joint occurs in a length of board or shingle lath, it must be in the centre of the rafter, or stud, and both joining ends must be securely nailed to the supporting timber.

70. The rough framing of the building may now be considered as complete. The skeleton is up and covered with its sheathing; the floor joists are in position, and the rough diagonal flooring is laid; the partitions dividing the interior are all studded, and the openings for doors and windows have all been framed and sawn out through the sheathing. It now remains for the carpenter to lath the partitions, brander and lath the ceilings, nail on the grounds that are to secure the wainscot and other finishings, etc., on the inside of the building, and to set the frames for the windows and doors, apply the outside casings, put on the *clapboards*, or *siding*, and shingle the roof on the exterior of the building; his work will then be practically complete until after the joiner and painter have finished. In many localities, the lathing is done either by special lathers or by plasterers.

71. Before the walls are lathed, it is sometimes desirable, in buildings where the ceilings are high, to provide a line of strutting or bridging between the studs, as shown at h', Fig. 42. The strutting tends to make the walls stiffer sidewise, and the studs are thus prevented from warping. At f' is shown a filling of *brick nogs*, as they are called, from the top of the foundation wall to the top of the beams. This nogging consists of pieces of old or broken bricks laid in lime mortar so as to completely fill the spaces between the studs and up to the top of the joists, thus not only closing a passageway for cold draughts from the cellar, but also preventing the rapid spread of flames in case of fire. The brick nogging may, with advantage, be continued up three courses higher than the joists, between the studs, which will prevent draughts at the floor level, caused by the

circulation of the air through the channels between the studding. Sometimes, where brick is not convenient, short pieces of 4″ × 2″ studs are filled in and spiked to the sill and joists.

ROOF FINISHINGS

72. Gutters.—In Fig. 43 is shown one method of finishing the rafters and forming a standing gutter. A rafter *a b e f d c* is notched over the plate *g* at *c d* and projects beyond the plate at *d f*. The portion of the rafter below *c d* is cut away to lighten the appearance of the eaves. At *h* is a tie-beam, which is spiked

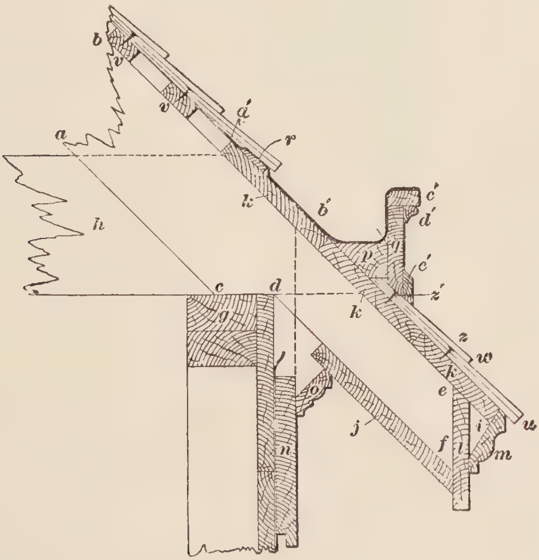


FIG. 43

to the ends of the rafter on each side of the building, and in this case also forms the ceiling joist of the upper story and rests on the plate *g*. From the top of the tie the rafter is closely boarded with 1-inch boards *k*, the lower one of which is allowed to project about half its width beyond the end of the rafter at *e i*. The end of the rafter is cut on the line *e f*, which is parallel to the plumb-cut at the ridge, and the soffit or plancher *j* on the bottom of the

rafters has its outer edge bevelled to the same angle, as has also the top of the fascia *l*, which finishes the ends of the rafters. A moulding *m* is then secured in place at the eaves by nailing it to both the projecting roof board *k* and the front of the fascia *l*; this gives a finish to the projecting eaves, and the under side is completed by the insertion of the moulding *o* between the soffit *j* and the frieze, or top casing, *n*. This finish is usually called a *box cornice*, in that it is formed by a boxing, or casing, of wood. Over the roofing boards, and outside the line of the front of the building, a bedplate *p* is nailed securely to each rafter to form the gutter, as will be explained further on. Four other forms of box gutters are shown in Figs. 44 to 47; the gutters shown in Figs. 44 to 46 are for frame buildings, and that in Fig. 47 for a brick building. Fig. 46 shows a gutter formed of sheet metal running well up under the shingles and over the eaves moulding of the cornice itself. This gutter stands entirely free above the surface of the roof and is braced every 3 feet by metal straps, as shown.

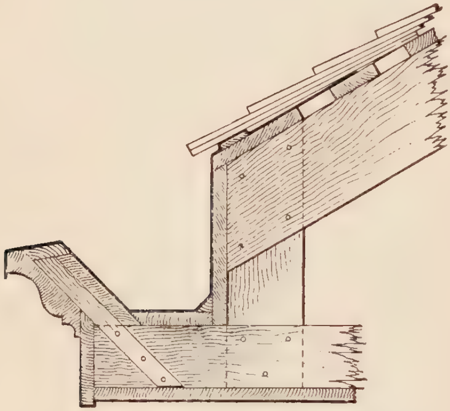


Fig. 44

73. Roof Covering.—In America and the Colonies, roofs of framed buildings are variously covered with wooden shingles, steel shingles, slate, tin, lead, zinc, corrugated iron, copper, or tiles. A flat roof should always be covered with tin, copper, or other material that is practically one piece, as water will run back between the joints of shingles, slates, or tiles, and thereby get into the interior of the building. A pitched roof may be covered with any of the materials mentioned, but shingles, slate, or tiles are generally used.

74. Shingling.—Shingles are laid on the roof of the house, either on sheathing boards, as shown at *k*, Fig. 43, or on shingle laths. The latter method is preferable, as it gives better ventilation to the under side of the shingles and prevents the accumulation of moisture at that place. When boards are used as a roof covering on which shingles are to be laid, they should not be laid close, as at *k*, except over the eaves. **Shingle laths** *v* are usually 2 inches by $1\frac{1}{4}$ inches or 3 inches by $1\frac{1}{4}$ inches, and are laid at right angles to the rafters and from 4 to 8 inches on centres, according to the exposure of the shingles to the weather. The amount of this exposure also determines the length of shingles that can be used with the greatest economy of material consistent with first-class work.

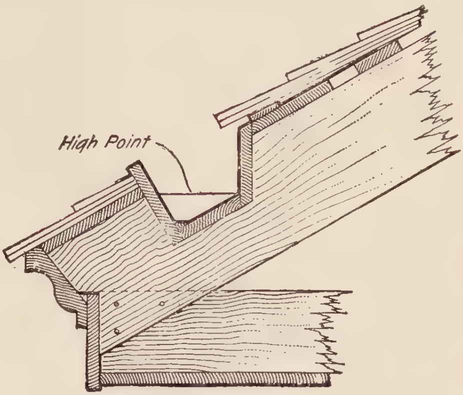


Fig. 45

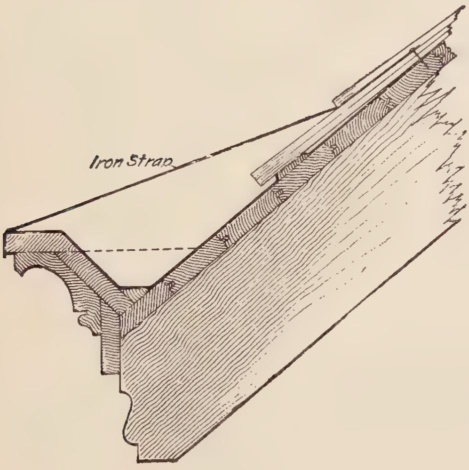


Fig. 46

75. Shingles.—Shingles vary in length, and can usually be obtained in regular sizes of 16, 18, and 24 inches in length, and from 4 to 8 inches in width. The size to be used in each case should be about 3 inches longer than three times the length exposed to the weather. The first course of shingles is placed

at the eaves, being laid double with broken joints, as at u, Fig. 43, in order that water finding its way through the joints of the upper layer may not readily percolate through the lower layer and rot the roofing boards, fascia, etc. When the first course is laid, each shingle is nailed with two nails about 2 inches above the upper line of its exposure; the amount of exposure is then measured back from the lower, or butt, edge of the shingles, and a line is struck by means of a chalked cord, to which line the butts of the next course are laid, as at w. This protects the nails driven into the previous shingles by the 2-inch lap shown at $z\,w$, and the nails of the second course also pass through the upper ends of the first course, as at z'.

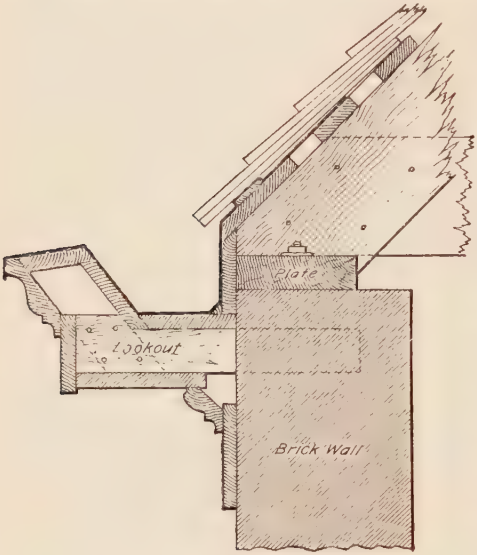


FIG. 47

76. After the shingling is completed up to the gutter plate p, Fig. 43, which in this case requires but two courses, the gutter face board q with its lower edge bevelled to fit the top of the shingles is set in place. A plinth e', a cap member c', and bed mould d' may now be nailed in place. In lining the gutter with copper or tin, a strip of hoop iron should be nailed along the edge of the cap c', allowing the lower edge to project below the cap. To this edge the metallic lining may be clasped, from which point it extends across the bed of the gutter to b' and up as far as a'. It is well to have the metallic lining extend 5 or 6 inches under the shingles. When the first course of shingles above the gutter is laid, the course is doubled for the same

reason that it is at the eaves. As these shingles are the lowest on the roof, they get the most water and are therefore more liable to rot. To prevent this, a tilting fillet is placed as shown at *r*. This fillet raises the shingles off the roof and allows the air to circulate better under them, thus facilitating the drying out after a rainstorm. The remainder of the roof from here up to the ridge is shingled, one course at a time, as already explained.

77. **Gutter Lining and Rain-Water Pipes.**—The lining of a gutter should be of the best quality of material, with all the joints properly folded, if of tin, and well soldered. The lining should also be painted on both sides and well fitted to the gutter. The gutter plate *p*, Fig. 43, is made of a varying width, so that the gutter has a gradual pitch toward the rain-water, or outflow, pipe, placed at the lower end. This rain-water pipe is usually made of tin, corrugated galvanized iron, or copper pipe from 2 to 6 inches in diameter, according to the size of roof from which it must carry the water. Where the area of a roof is very great, more than one pipe may be necessary to carry off the accumulation of water during a heavy rain. A liberal allowance is to provide 1 square inch of pipe section for each 75 square feet of roof area ; but never to use a pipe less than 2 inches in diameter. Even that size is liable to become choked and clogged with dirt or leaves in a wooded section of country, and should be used only for veranda, porch, bay-window, and other small roofs. The pipe is inserted through the bottom of the gutter and its metallic lining, and must be well soldered to the latter, while its *throat*, or inlet, should be countersunk, and protected with an open iron grating or wire screen, to prevent foreign substances from entering with the water.

78. **Flashing.** — **Flashing** is a term given to all sheet-metal work used in connection with roof covering to ensure a water-tight condition at joints and angles. Flashings are required on hips, valleys, ridges, and eaves, round hatches, skylights, gables, flanks of dormer-windows, etc.

On shingled roofs, where angle rolls are not used at the hip, pieces of flashing are laid on the hip over each course of shingles or slate in the same manner that a shingle or a slate itself would

be laid, if it could be bent to fit round a corner, as shown at *a*, Fig. 48; for, while the joints between the various pieces of roof covering may be broken, or alternated, as at *b*, in the main flat slopes, the hips must have a continuous row of joints from the eaves to the ridge, as at *c*, and the insertion of flashings under the shingles at these points prevents the water that would work its way beneath the covering from getting into the interior, and carries this water to the flat slopes, where it may run off harmlessly.

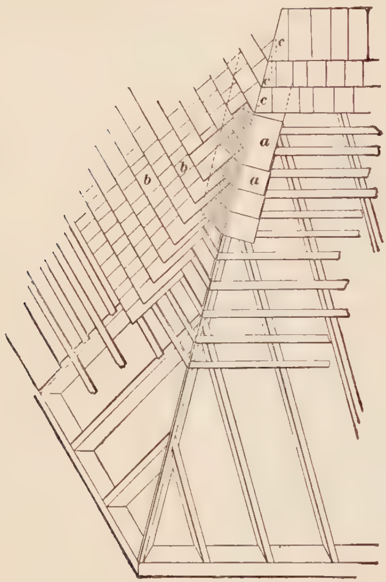


FIG. 48

79. In valleys, the conditions are in some respects reversed. On the hip of the roof there is no accumulation of water at any time, and what little may fall there is immediately drained off by the pitch; but in the valley there is a depression between two slopes, and all the water falling on each of them is immediately carried to the valley. The valley therefore acts as a gutter, and is flashed accordingly. A continuous gutter is formed in the depression, and the edges of the flashing are turned up about 6 inches under the shingles. The shingling is not carried down to the intersection of the slopes, but is stopped about 5 inches from the valley rafter, and the gutter is thereby left open. The flashing of all such situations is treated in *Roofing*.

80. A shingled roof is rendered water-tight along the ridge by a number of methods, two of which are shown in Figs. 49 and 50. The plan shown in Fig. 49 is used on a shingle roof that requires no flashing, while in Fig. 50 a metal flashing is used on a slate or flat-tile roof. In Fig. 49, the ridge plate *a* is carried above the line of the shingle lath *b* and the top of the shingles *d*,

and its top is bevelled off to conform with the general pitch of the roof. After the shingling is complete, the top of the ridge is finished off to form a continuation of the top surface of the last course of shingles, and the *ridge boards* *c* are nailed to it and to each other in the position shown. Before the ridge boards are nailed in place, there should be a layer of two-ply roofing felt folded over the ridge, on top of which the ridge boards may be firmly nailed; this will assist in making a thoroughly water-tight job. These ridge boards are usually from 1 inch to $1\frac{1}{8}$ inches in thickness, and from $5\frac{1}{2}$ to 9 inches in width, according to the amount the shingles are exposed to the weather. The *ridge roll* *e* is formed from a single piece of wood, is from $2\frac{1}{2}$ to 3 inches in diameter, and is rabbeted at *f g h* to fit the angle at the top of the ridge boards. This **V**-shaped groove, or rabbet, should be deep enough to permit the edge of the roll *h* to lap well over the joint between the two ridge boards *c*.

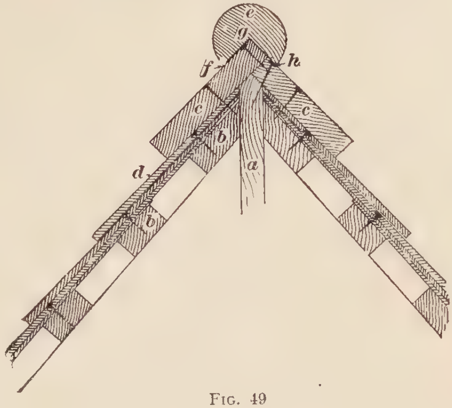


Fig. 49

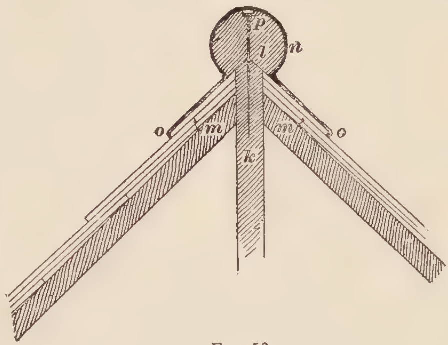


Fig. 50

81. In Fig. 50, the slating of the roof *m* is carried up to the bevelled end of the ridge plate *k*, butting against it as the shingles do in Fig. 49 and the wooden ridge roll *l* is rabbeted over the joints formed at the ridge. This roll is held in place by long

spikes p driven through its top into the upper edge of the ridge plate, and over it is sprung the galvanized-iron covering n, which has been previously shaped to fit the roll and catch the under edge of the last course of slates, as at o. Ridges, like hips, are very slightly subject to leakage, and, as little water falls on them or remains after it has fallen, the same precautions are not required with flashings at these points as would be necessary elsewhere.

82. Around skylights and dormers, where the sill rests on the slope of the roof, flashing is applied so that it extends under the roof covering, adjacent to the sill and turns up and over the sill itself in such a manner as will prevent any possibility of water entering between the sill and the slate or shingles. The sides of a dormer, where they intersect with the roof pitch, are flashed in the same manner as are the valleys, except that the shingling or other covering may be carried up close to the finished sides.

83. Precautions to be Observed in Roofing.—Great care must be observed along the eaves of a roof, especially where that roof is over a well-heated room, as the interior heat during the winter will cause the snow on the roof to melt and run to the eaves, where, relieved from the effects of the high temperature, it freezes and builds up a dam of ice, and the accumulated water backs under the shingles and gets into the house. Under these conditions, it is sometimes desirable to build the gutter above the line of the plate, in order that the same heat that melts the snow may sufficiently warm the gutter to prevent it from freezing up when its services are most needed. In the case of a shingled roof, unless the pitch is at least 45° above the horizontal, there is much danger of leakage during windy weather, as a high wind will drive the water under the shingles and through the first crevice that presents itself, hence the importance of exercising the greatest care with all the flashings, and of securing broken joints in each course of shingles. Shingles with loose knots or open knot holes within half their length of the butt, or shingles that are split, or shaky and liable to split, should be rejected. Rejected shingles should be broken or cut through with a hatchet, to make their use impossible. This small loss is nothing compared with the expense and inconvenience of a leaky roof.

CARPENTRY

(PART 4)

CONSTRUCTIVE DETAILS

PLASTER GROUNDS

1. **Plaster grounds** are strips secured to brick and stone walls and to the studs of frame partitions for the purposes of receiving the finishings and of stopping the plaster at breaks and openings. They consist of strips of wood from $\frac{5}{8}$ to $\frac{7}{8}$ inch thick and from 2 to 3 inches wide, according to the purpose they are to serve. Great care must be taken to place grounds correctly to line and level, always keeping in view the character and dimensions of the finishings. The edge of the ground abutting the finished plaster should always be bevelled, so that the plaster can be more securely bonded, or keyed.

2. In Fig. 1 is shown a method of applying grounds to which a skirting may be fastened. In the angle formed at the meeting of the stud partition and the rough floor, a strip 2 inches by 1 inch is nailed to the studs, and at about the height of the skirting above and parallel with this strip is nailed a similar strip. The upper edge of the ground is kept $\frac{1}{2}$ inch below the top of the skirting, so that the latter will further bind the plaster in place. The upper edge of the strip is sometimes left square, but the plaster is better bound in place when the edge is bevelled, as shown by the upper strip in the figure. To these strips the skirting is nailed after the plastering is dry.

In dining rooms, kitchens, billiard rooms, etc., where a chair rail, or dado, is to be placed, another ground about 4 inches wide

is nailed to wall plugs or to the studs, from 2 feet 6 inches to 3 feet above the floor, according to the height of dado. Sometimes, also, a strip 1 inch in width is nailed from 1 foot to 2 feet 6 inches below the ceiling to receive the picture moulding. This last, however, may be placed directly on the surface of the plaster, wire nails being driven into the wall plugs in the case of

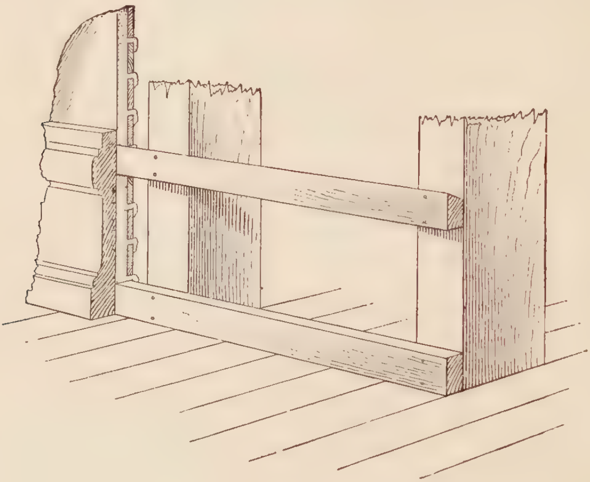


Fig. 1

brick partitions or walls, or into the studs in the case of timber partitions. Where a wooden cornice is to be carried round a room, a ground must be provided for it in the angle between the ceiling and the side walls. The surfaces of the stud partitions between these grounds are then lathed.

AVOIDANCE OF PLASTER CRACKS

3. Natural settlement caused by shrinkage of materials in a wooden partition is not easily overcome, and when large timbers are used it cannot well be avoided. Seasoned framing timber is scarce and expensive, and the average architect can at best but require "that all beams, joists, studs, and framing material must be as dry as the market affords," which eventually

means a series of cracks, seams, and fissures in the plastering. These are most prominent where the beams or joists run parallel with and support partitions, in which cases the partitions settle with the beams, leaving an ugly gap along the ceiling line. Where the beams sag in addition to shrinking, a series of zigzag diagonal cracks will appear on the surface of the wall. A similar effect will be noticed where a partition is supported by a tier of joists running at right angles thereto, and where it is placed at

FIG. 2

or near the centre of the span; all the joists shrink, but those near the centre of the room sag more than those adjacent to the walls. To avoid these defects, it is necessary that the supporting beams and joists should be thoroughly seasoned and of sufficient strength to carry the load without perceptible sagging. Whenever practicable, joist-bearing partitions should be placed directly over each other, the "feet" of the upper studs resting on the plate of the lower partition. By this means a continuous line of support is obtained from the basement or foundation wall,

where, if expense is a secondary consideration, a steel **I** beam or arched brick wall should be used instead of a wood supporting beam.

4. The practice of setting partitions promiscuously on the joists is to be condemned, on account of the distorted condition of floor levels, door frames, and doors likely to result. The effect of interposing a joist or joists in the thickness of a partition is shown in Fig. 2, which illustrates a carefully designed and well-executed piece of joinery. In this case, the trimmer beam was set flush with the face of the partition on the staircase side, as suggested in Fig. 3, and the laths were simply nailed on the face of the beam. The beam, if 10 inches deep, might shrink from $\frac{1}{4}$ to $\frac{3}{8}$ inch, which means that the upper partition would drop down that much, and that the plaster, not being elastic, would bulge and crack. Had the trimmer been placed as shown in Fig. 4, in which the studs are continuous, plaster cracks would not have occurred.

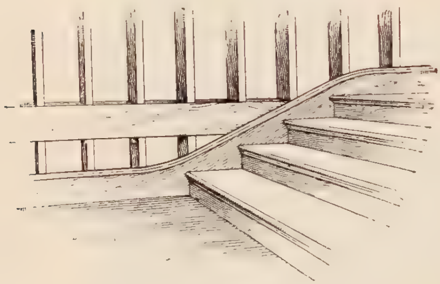


Fig. 3

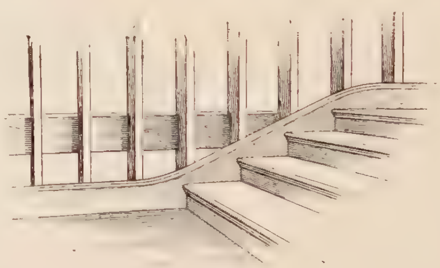


Fig. 4

5. Where a brick chimney stack passes up through the centre of a house that is divided internally by means of timber-framed partitions, it should be placed with particular reference to the partitions abutting on it. In many cases the studs are set back just the thickness of the laths from the face of the stack, as shown at *A*, Fig. 5. This is a grave error, the sure outcome of which will be cracked and broken plaster, as there is always a

certain amount of settlement in the brickwork. One of the first considerations necessary is that no timber-framed partitions should be put in position until the roof is on and the building has had time to settle. Another point to which careful attention should be given, with relation to a chimney stack running through a building, is that the stack should be built free to move in a vertical direction. Where partition studding is placed in the manner shown at *B*, Fig. 5, this can be readily done.

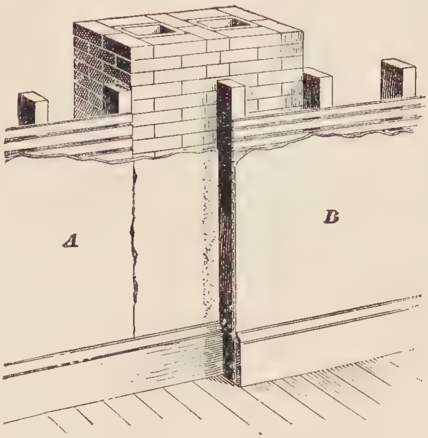


FIG. 5

Cracks that subsequently occur will be in the internal angles, where they are not so noticeable and where they can be readily repaired without destroying the appearance of the walls. The heated brickwork of the stack also causes the studs to dry rapidly and to warp, thus producing a rift between the wall and the stack.

6. When joists or studs are over 2 inches thick, they should have a strip nailed on their edge, thus affording a better key for the plaster. To provide for this, and also to avoid cracks resulting from the joists becoming warped and twisted while drying, it is customary in good work to brander the ceilings with $1\frac{1}{4}'' \times 1''$ strips set at from 12- to 14-inch centres and well nailed to the joists. In this connection, the joists should be well strutted with herring-bone struts. A row of zigzag strutting in the height of studs of partitions will also render effective service and prevent them from twisting.

All external and internal angles of stud partitions should be made firm and rigid, otherwise subsequent shrinkage will cause the wall surfaces to separate and show fissures that cannot be closed. When a partition meets another at right angles, the

practice of running the laths of the one across the back of the abutting partition stud and simply butting the laths of the partition against it is bad, and should never be tolerated.

False jambs, where used, should be well nailed to studs at door openings, so that the slamming of doors will not bring any strain on the plaster behind the casing.

Suitable plaster grounds should be placed for all skirtings, dados, and door and window finishings, especially where they adjoin brickwork. It is particularly necessary that the grounds should be of good seasoned stock, as the slightest shrinkage will disturb the plastering when the finishings are attached.

7. Unskilful and careless lathing is also responsible for many plaster cracks. Laths should be properly seasoned and secured from being soaked by rain-water after they have been seasoned. When laths are unseasoned or have been carelessly piled and used in a wet condition, they will subsequently shrink and cause the appearance of an endless series of seams. The laths should not be too dry and parched, or they will absorb the valuable moisture from the plaster and cause it to become powdery and lose its toughness. This trouble, however, can be avoided by sprinkling the laths with water before applying the first coat.

Cross-grained laths are to be avoided, as in drying they curl and warp, break the bond of the plaster, and cause cracks. In good work, where sawn laths are used, none but straight-grained material should be allowed.

Where studs are set at 16-inch centres, laths should not be less than $\frac{3}{8}$ inch thick; laths thinner than this yield under slight pressure and strain the plaster. A wall properly lathed and coated with $\frac{5}{8}$ inch of common haired plaster, when thoroughly dried, should, when struck with the hand, be firm and compact and sound like a drum.

WEATHER BOARDING

8. **Weather boarding** is the term applied to the material with which the exterior of a timber-framed structure is covered. It is largely used in the British Isles for covering barns, sheds,

and country cottages; but in the Colonies and in America it is used to a great extent as a covering for the outside of timber-framed houses so much in vogue for residential and business purposes. In America, two distinct kinds of weather boarding, or siding, as it is termed locally, are used; namely, *bevelled siding* and *novelty* or *German siding*.

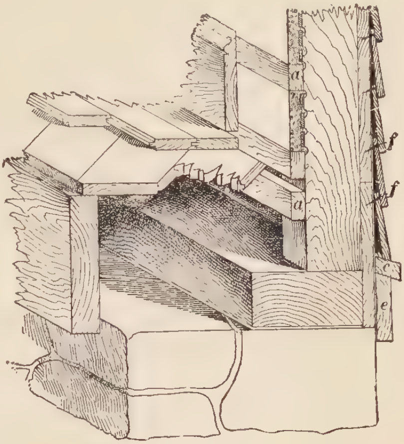


FIG. 6

Bevelled siding consists of sawn and planed boards in commercial lengths of about 16 feet and width of from 4 to 6 inches. The thickness of this kind of siding is $\frac{5}{8}$ inch at one edge, bevelling back to $\frac{3}{8}$ inch at the other edge, as shown in Fig. 6.

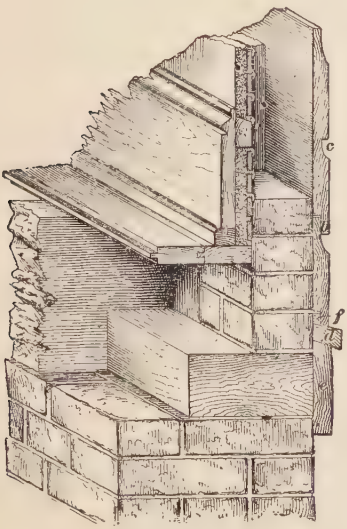


FIG. 7

Novelty siding has a uniform thickness of about $\frac{7}{8}$ inch, except where it is rebated at the bottom to receive the chamfered edge of the next board below, and where it is chamfered at the top to fit the rebate of the board next above, as shown at *b*, Fig. 7. Novelty siding is manufactured in single widths of from 5 to 9 inches, although in very cheap grades of work it is used in double widths, with a groove worked lengthwise through the middle to imitate the joint, as shown at *c*, Fig. 7.

The depth of the rebate and the width of the chamfer limit the amount of lap that can be

made with novelty siding; whereas, with bevelled siding, one course may overlap the other any distance within the limits of the width of the material. It is preferable, therefore, to use bevelled stock on all first-class work, though it costs a trifle more and requires more labour to put in place. Bevelled siding is more durable on exposure to the weather, less liable to crack and check, while its thinness renders it easily dried out; the stock, also, is more likely to be well seasoned than that used for novelty siding.

9. Method of Siding a Building.—Before the siding is put on the building, a *water-table* e, Fig. 6 and Fig. 7, extending about 1 inch below the sill, is placed all round the structure. The water-table has a pitched cap, shown at c, Fig. 6, and d, Fig. 7, which serves the purposes of receiving the water that runs down the side of the house and of shedding that water to the ground before it works its way into the foundation, to rot the sill and render the house damp and unhealthy.

The cap of the water-table is pitched in order to give its top surface an inclination of from 15° to 30° to the horizontal; it also has a tongue worked on its top so as to form a seat for the lower piece of siding and thus make a water-tight joint, as shown at f, Fig. 7.

It is usual to lay over the sheathing of the building, from the water-table to the plate, one or more thicknesses of heavy felt or resinous building paper, to prevent draughts from working through the cracks and joints. Over this paper, and above the water-table, the siding is laid in horizontal courses, each course being nailed through its lower edge, as shown at f, f, Fig. 6. Cut nails $2\frac{1}{2}$ inches long and having flat heads should be used, the siding being nailed only at the studs and the nails set in so that they may be puttied over. Bevelled siding should be carefully gauged as to lap, so that the edges may be made to run in line with the horizontal lines of the window and door finishings.

10. Circular Weather Boarding.—When a circular tower of a semicircular bay window exists in a building, the weather boarding must have its lower edge convex and its upper edge

concave, in order that these edges may lie in horizontal lines when the weather boarding is bent round the curved front of the tower.

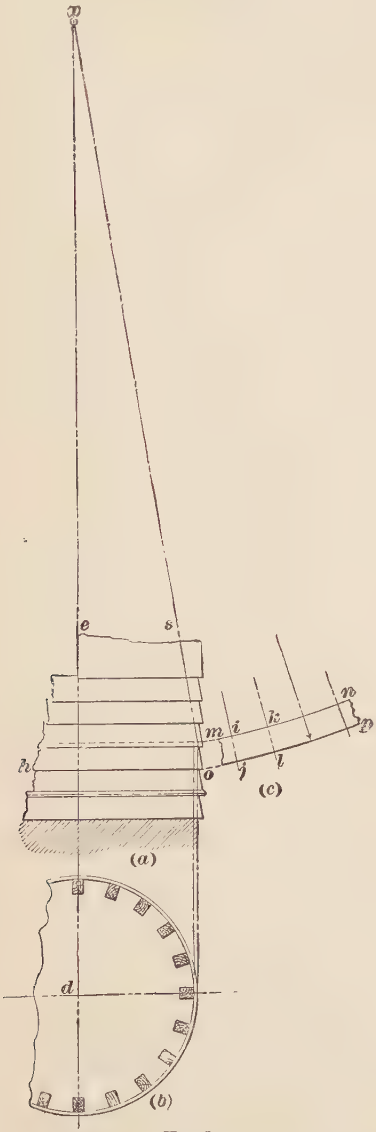


Fig. 8

Fig. 8 shows the elevation (*a*) and plan (*b*) of a portion of a circular tower, the weather boarding of which must be worked with curved edges, as shown in (*c*). To find the radius and extent of this curvature, an axial line *d e* is drawn through the centre of the tower and prolonged toward *e* indefinitely. A line *o s* is then drawn as a continuation of the direction of the inside slanting surface of one piece of the weather boarding, and prolonged until it intersects the axial line *d e* at *x*. With this point of intersection *x* as a centre, and radii equal to *x o* and *x m*, respectively, the arcs *o p* and *m n* are described. Then, the figure *m n p o* will be of the form and curvature necessary to secure the level lines on the top and bottom of the weather boarding after it is bent round the tower in the position shown at *o h*.

This form *m n p o* should be first cut out of heavy paper, and then, using the paper as a pattern, the curve can be traced on each strip

of weather boarding and worked out with a knife and plane. The exterior distance from centre to centre of the studs shown in the plan (*b*) should be marked off on the pattern piece with lines converging toward the point *x*, as shown at *j i*, *l k*, and all the butt joints between the ends of two pieces of curved weather boarding should be cut on one of these lines, in order to ensure a properly fitting joint and to have the ends meet in the centre of a stud. When the weather boarding is put on the building, its lower edge is laid and nailed to a line previously marked for it on each stud.

Where the weather boarding is specially worked with a vertical back, so as to hug the sheathing, it can be applied in straight pieces. In this case the surface of the tower is *cylindrical*, while in the other, where bevelled weather boarding is used, the surface of each layer is *conical*.

VERANDAS

CONSTRUCTION AND DESIGN

11. Because of their exposed situations, the details of construction of the exterior features of a building require special consideration, in order that the purposes required of them shall be fulfilled. Veranda construction must provide all the requirements of an outdoor sitting room in fair weather, and at the same time ensure the side of the house on which it is built against the invasion of water and dampness during a heavy rainstorm; it must also permit the rapid drying of the floor and timbers after such a storm.

12. Details of Veranda Construction.—In Fig. 9 is shown a perspective view of the details of construction of a veranda. The floor *d* slopes at the rate of $\frac{1}{4}$ inch to a foot from the house line to the front edge at *c*, in order to drain off the water as soon as it falls. For the same reason, the boards of the floor are laid across the veranda, as shown; otherwise, the water would lodge in the joints and soon rot the material.

In order to run the floor boards in this direction, it is necessary to provide means of framing the floor joists lengthwise of the structure. Therefore, a girder *b* resting on a plate, or template, *g* extends across the opening and rests on an offset in the wall of the house, where it again rests on a plate, or template, or, where the veranda is narrow, the girder simply rests on the brickwork without any template or plate. The veranda floor joists *c*, *c* are then framed into the girder, as shown at *h*, and securely

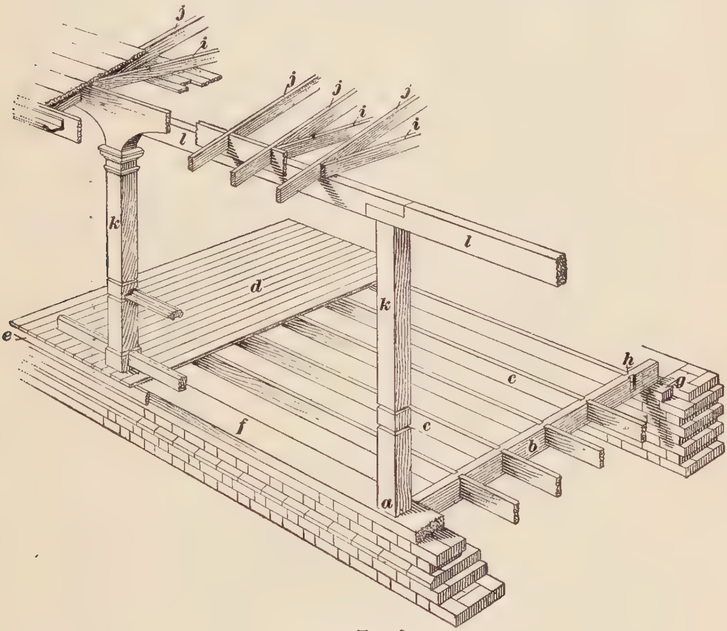


FIG. 9

spiked in place. In order to secure the necessary pitch of $\frac{1}{4}$ inch to the foot for the veranda floor, the girder *b* may be laid at the necessary inclination ; or its top may be either planed or sawn down, so that it has the proper pitch, the bottom being allowed to remain level. In either case the beams are framed so that their tops are flush with the top of the girder, and the flooring *d* is laid directly on them.

13. Flooring.—Veranda flooring should be at least $1\frac{1}{4}$ inches in thickness, tongued and grooved, and laid in white lead ; that

is, the joint between two boards should be thoroughly filled with a pasty composition of white lead and raw linseed oil. This is accomplished by coating the edges of the boards with the mixture and driving them tightly together as they are laid. A good material for veranda floors is clear, dry, selected redwood, red pine, teak, or other hardwood of heart stock, free from all imperfections.

14. Posts.—Veranda posts, whether square, as at *k*, Fig. 9, or turned, should be of selected, good, sound, dry timber, which is

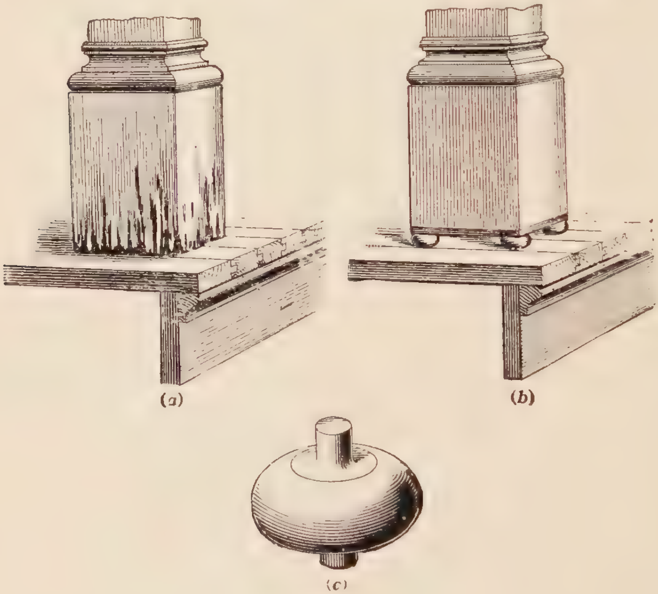


FIG. 10

the heart wood of the tree. After being squared to the required dimensions, the posts are carefully sawn squarely across the ends to an even length. The pores of the lower end of the wood should then be filled with white lead, or other preservative material, and the post set up in position.

Porch posts placed directly on the porch floor will soon rot, as shown in Fig. 10 (*a*). For this reason, the bases of porch posts are often placed on metal shoes or cast-iron buttons, 1 inch thick

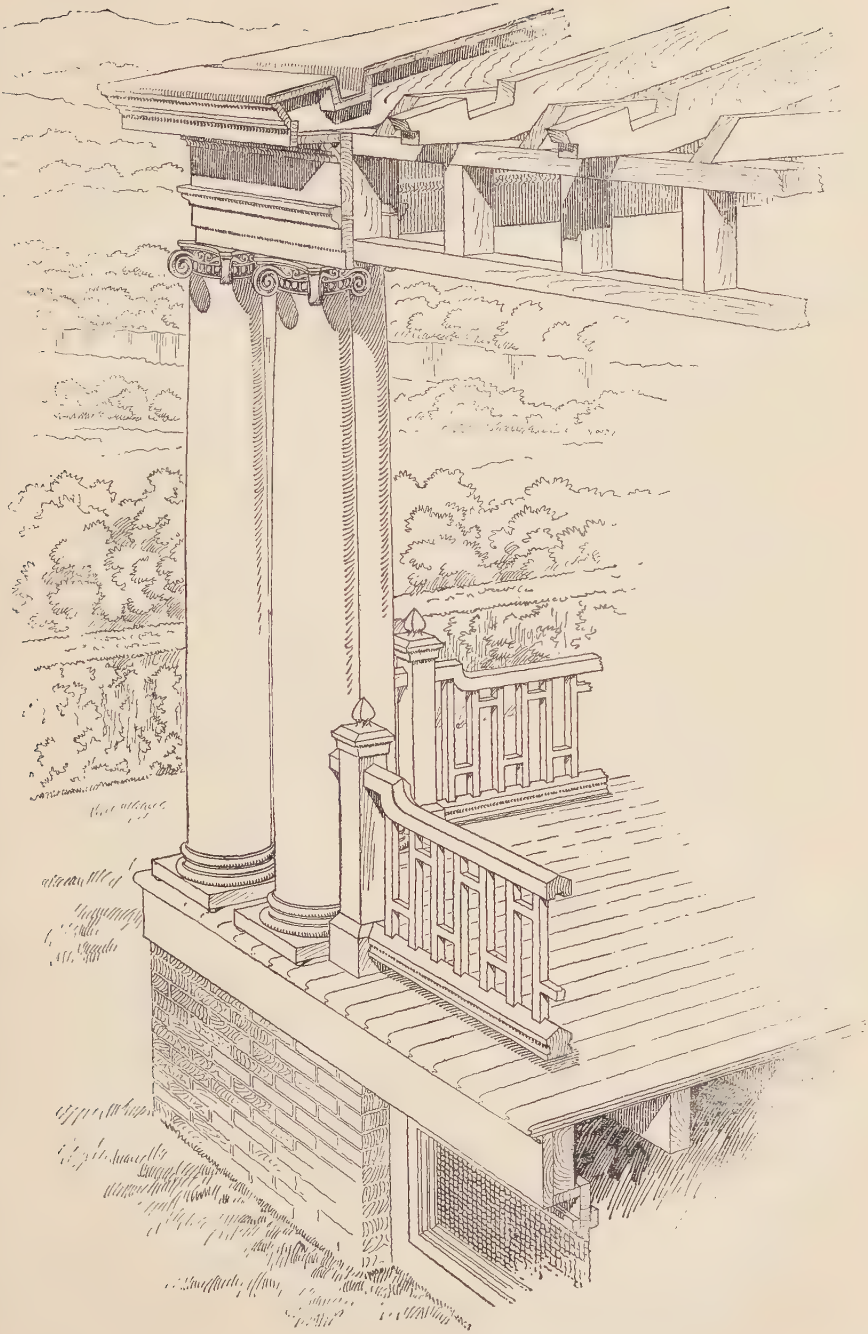


FIG. 11

and 2 inches in diameter, which raise them clear of the porch floor. Fig. 10 (*c*) illustrates such an iron button. Four of these buttons are placed under a square post, the metal pins being let into the floor and the post and bedded in white lead. Another method is to rivet the buttons to an iron plate, which in turn is secured to the bottom of the post, as shown in Fig. 10 (*b*).

15. A head *l*, Fig. 9, connects the upper ends of the veranda posts and serves to support the ceiling joists and rafters *i* and *j*. The inside ends of the joists and rafters could be notched over a head in a similar manner, but in brick or stone walls they are built in and anchored.

16. Roof.—The roof of a veranda, such as illustrated in Fig. 9, which slopes at the rate of 4 inches to the foot, should be boarded over with grooved and tongued roofing boards, and then covered with lead, zinc, copper, or other similar material, the inclination being insufficient for slates or shingles. The eaves is formed as shown by projecting the rafters over the head *l* and cutting their ends to a vertical face to receive the fascia board, on which is fixed the cast-iron gutter. This gutter should be fixed before the roof covering is finished, so that the lead or zinc may be dressed over it, thus securing a sound and water-tight finish.

17. The ceiling of the veranda may be formed of narrow strips of pine or hardwood, laid on and blind-nailed securely to each of the ceiling joists *i*. A better appearance is presented when the ceiling boards are placed at right angles to the building, in which case blocking or furring strips should be run at right angles to the ceiling joists. Sometimes the veranda roof is left open on the under side, exposing the timber construction. When this is the case, no ceiling joists are used, but the exposed portions of the rafters are planed and dressed; the roofing boards are of selected narrow stock, planed, grooved, and tongued, and laid with their finished side downwards.

18. Figs. 11 and 12 illustrate the method of construction used for a porch such as would be found in a house of the Colonial

type. At *a*, Fig. 12, is shown a method of changing the pitch of the porch beneath the balustrade so that the nosing at *b* may be level and line up with the water-table *c* of the building.

19. Chamfering.—The method known as chamfering is sometimes resorted to in order to relieve exposed timbers of the sharp angle, or corner, where their finished faces meet. It

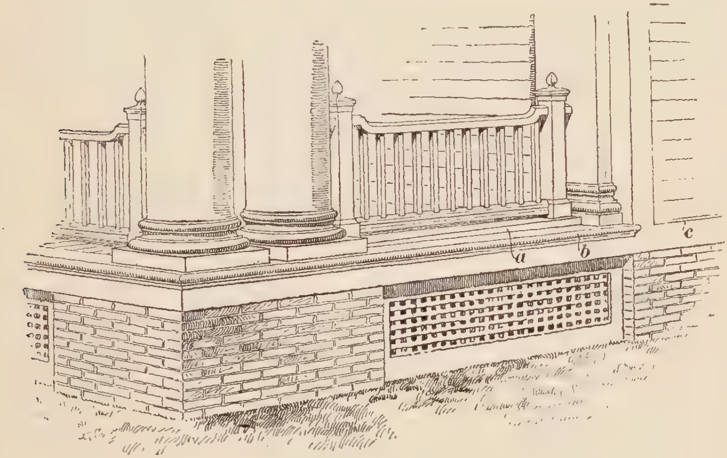


FIG. 12

consists of cutting off the corners of a beam, ceiling joist, veranda post, or other exposed timber for a part of its length, and of stopping the *chamfer* against an oblique cut, called the *chamfer-stop*, made at an angle of about 45° or 60°, as shown at *a b*, Fig. 13, where *b c* is one of the chamfered corners.

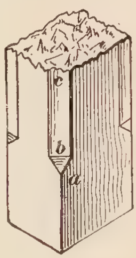


FIG. 13

20. Chamfered corners are very much used in joinery work. The width of a chamfered edge is entirely a matter of taste. Of course, the chamfer should never be so great as to impair the strength of the timber; on the other hand, it should be prominent enough to be clearly seen from any point where the timber so treated is conspicuous. This is especially the case with beams and floor joists, which, being above the eye, require a somewhat heavier chamfer than posts and rails.

CENTRES FOR ARCHES AND DOMES

FORMS AND CONSTRUCTION

21. Arch Centres.—Where the openings in brick or stone walls are to have curved heads, the carpenter will be called on to make and set in place wooden templates, or **centres,** as they are called, on which the arches can be built. These centres are allowed to remain in place until the mortar has thoroughly set and rendered the arch self-supporting.

22. Centre for Semicircular Arch.—In Fig. 14 is shown a wooden centre for a **semicircular arch** over a doorway in a

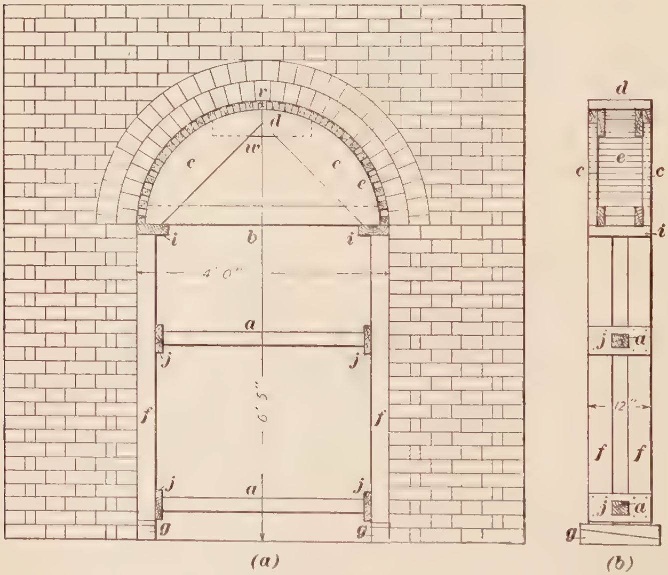


Fig. 14

$13\frac{1}{2}$-inch brick wall. At (*a*) is shown an elevation of the centre in position in the wall and its supports, and at (*b*) a section. The faces of this centre are each composed of two pieces *c* of

$1\frac{1}{4}$-inch plank sawn to the proper curve. These are held together at the bottom by the tie-piece *b*, which is securely nailed, as shown, while the joint at the top is secured by a fish-plate *d* nailed to both pieces on the inside of the boards.

Two face pieces formed in the manner just described are then joined together with small strips, called *lagging*, $1\frac{1}{4}$ inches thick, $1\frac{1}{2}$ to 2 inches wide, and 12 inches long, as shown at *e*. The bottoms of the face pieces are secured by two *caps* *i* nailed to each face, and under these caps are placed the supports *f*, when

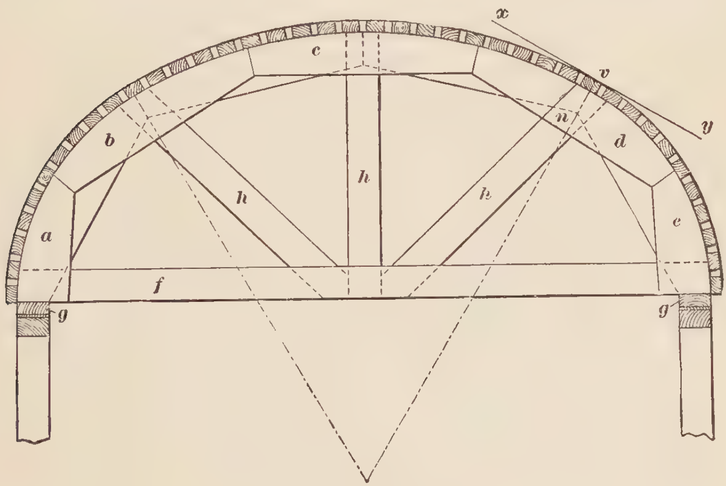


FIG. 15

the centre is set in the opening ready to be built on. The lower ends of the supports *f* should not rest directly on the sill of the opening, but on two slip wedges *g*, which are driven out by degrees after the brickwork has set, thus allowing the arch to settle down gradually to its own proper bearing. The braces *a* are inserted between the cleats *j* to maintain the supports in a vertical position against the jambs of the opening. All wooden arch centres may be framed in very nearly the same manner, except in very large spans, where heavier timbers must be used.

23. Semielliptical Centres.—Centres for semielliptical arches are formed in a manner similar to that followed in the case of semicircular arches, but usually require more pieces in the curved faces. For this reason, it is advisable to set out, on paper, a semiellipse of the required height and span, and make a template. Then, with this template, set out the curved line on the several pieces of plank that have previously been arranged to occupy about their proper position in the finished centre, as *a*, *b*, *c*, *d*, and *e*, Fig. 15. The curved edge is then sawn out on each piece

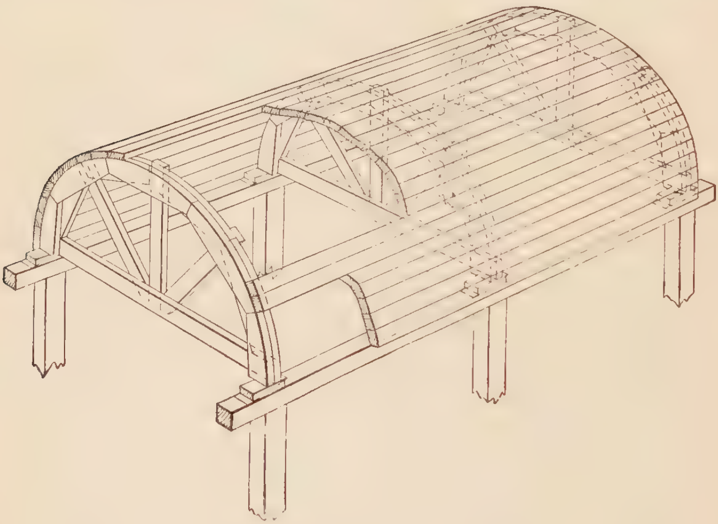


Fig. 16

separately, the ends sawn to the proper mitre line, and fish-plates nailed on the back in the same manner as *d* was nailed on *c* in Fig. 14. When great strength is required, it is sometimes advisable to make these fish-plates as large as their face pieces *a*, *b*, *c*, *d*, and *e*, and mitre their ends to an even joint, as shown in Fig. 15. The ends are secured in place by the tie-piece *f* and the caps *g*, while the centre is strengthened by struts *h*, *h*, *h* extending from the tie-piece *f* to each of the intermediate sections of the face pieces, as *b*, *c*, and *d*. Small 2″ × 1¼″ strips are then nailed on the curved edges in the same manner as for the semicircular

centre, their length being equal to the thickness of the wall in which the arch is to be built. A perspective of this arch centre is shown in Fig. 16.

24. Direction of Joints in Centres.—In all wooden centres, the joints between the different sections of the face pieces should always be in a line perpendicular to a tangent at the point where the joint line intersects the curved line of the arch. For example, in Fig. 15, the joint line $n\,v$ of the fish-plates is perpendicular to the line $x\,y$, which is tangent to the curve at v. When the arch is semicircular, all these joint lines will converge toward the centre from which the curve is struck, as $v\,w$, Fig. 14, but in other curves they can be found only by first drawing the tangent, as in Fig. 15.

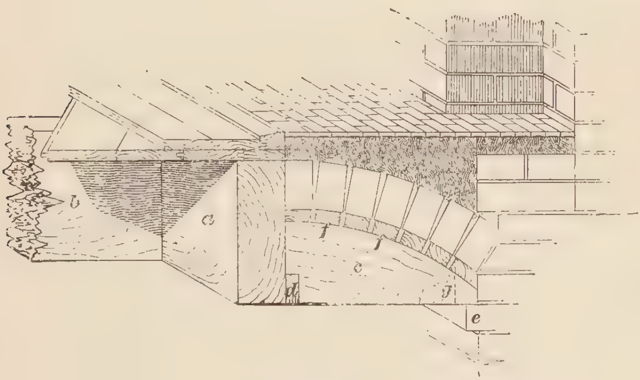


Fig. 17

25. Trimmer-Arch Centres.—Centres for trimmer arches are built to extend from the brick-wall face of a chimney breast to the trimmer of the floor, where it is framed round a fire-place opening, as shown in Fig. 17.

A characteristic difference between the trimmer-arch centre and those previously described is that the wooden centre is generally left in place and remains in the building after the brick arch is set over it. When the bricklayer builds the brickwork of the chimney, he corbels out one course of bricks about $1\frac{1}{2}$ inches at the level of the under side of the floor joists, as shown at *c*.

The carpenter then builds the centre so that one end rests on the brickwork at *e* and the other end is notched over a $2\frac{1}{2}''$ or $3'' \times 1\frac{1}{2}''$ cleat *d* nailed on the trimmer *a*. The face piece of the centre *c* is $1\frac{1}{4}$ inches thick, and its upper edge, on which the lagging *f, f* is nailed, is sawn to the curve of the arch, so that the small end will be about $1\frac{1}{2}$ inches thick where it rests on the brickwork at *e*, and about $4\frac{1}{2}$ or 5 inches less at the large end than the depth of the floor joists. The number of ribs like *c* required for a trimmer-arch centre depends on the length of the hearth that is to be built over it. If the ceiling below is to be plastered, however, it is desirable to have a rib opposite each floor joist supported by the trimmer, thus avoiding waste of laths. Where the distance of the trimmer is not more than 18 inches from the face of the wall, the laths may be run at right angles thereto and nailed at the wall end to the cleat *g*.

26. Dome Centres.—When the roof of a building is carried up, either wholly or in part, in the form of a hemisphere, or semiellipsoid, it is called a **dome,** and the rafters supporting it must be sawn or bent to the required curvature.

27. Hemispherical Dome.—A **hemispherical dome** is shown in Fig. 18, in which (*b*) is a half-plan and (*a*) the section. The curve of the dome is described from *s'* as a centre with a radius *s' e'*. This is also the curve of the outside of the rafters. The centre of the plan *s* is the point from which is described the curved outline of the plate *a*, on which rest the feet of the rafters *f, f*. At *c* is the upper plate, which receives the upper ends of the rafters *f* and at the same time forms a circular opening, called the *eye of the dome,* admitting light and air. About half-way up the curved outline, at *b'*, is shown a line of purlins cut in between the main rafters to receive the upper ends of the small jack-rafters *g, g*. This line of purlins is shown at *b* in the plan, and it is at about this point that the main rafters are spaced at a uniform distance of from 16 to 24 inches apart, the jack-rafters being then inserted between their lower ends and spiked to the plate *a* and the purlins *b*.

The method of forming, or building up, the plate *a* is identical with that described for the conical roof in *Carpentry,* Part 3,

the rafters being bent or sawn in the same manner as the curved rafters of the ogee roof there described. Where bent rafters are used, they are composed of thin strips bent over a form, the layers being nailed together. When the dome is for exterior effect only, and the inside is not to form part of any particular room, the rafters need not be sawn to a curved line on the under side, but may retain the straight edge of the board from which it is sawn, as shown by the dotted line $v' w'$, or, if composed of two pieces, by the lines $x' y'$ and $y' z'$.

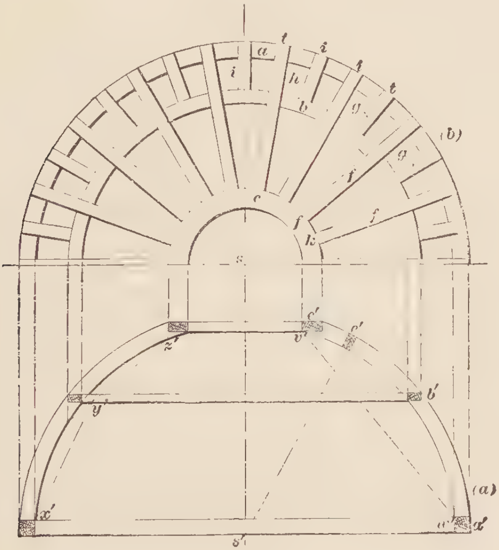


FIG. 18

28. **Methods of Boarding Hemispherical Domes.**—There are two methods of boarding over the curved surface of hemispherical domes. The first method is shown in Fig. 19, where $n\ o\ f$ is the curve of one-half of the plan of the dome, and $a\ b$ is the outline of the curve of the elevation. From the centre c of the plan is drawn a line $c\ d$ of indefinite length, but at right angles to $c\ b$, the axis of the elevation; and at $e\ r$ on the plan is set off the width of one of the roofing boards, $o\ e$ and $o\ r$ being each equal to one-half the width of a board. The lines $e\ c$ and $r\ c$ then

represent this board in place on the plan. The line $a\,b$ is then divided into any number of equal parts, the points of division being marked s, s_1, s_2, etc., and these parts are set off on $c\,d$ from o, so that $o\,d$ represents the length of the line $a\,b$ folded out straight, and $o\,f$, $o\,f_1$, etc., are each equal to $a\,s$, $a\,s_1$, etc. From s, s_1, etc., perpendiculars are now drawn through $c\,o$, cutting $c\,e$ and $c\,r$ at l, l_1, etc. From the points f, f_1, etc., on the line $o\,d$, draw lines at right angles thereto, and make $t\,f$ equal to one-half of $l\,l$, $t_1\,f_1$ equal to one-half of $l_1\,l_1$, etc. A curved line drawn through the points t, t_1, etc., to d will be the outline of the *gore*, or covering board required, and if this is set out on a sheet of heavy paper and cut to the lines, it will form a template from which all the boards may be marked and cut. To support the gores, curved purlins, as shown at c', Fig. 18, are inserted between the rafters. Great care must be taken that these purlins are spaced to suit the curvature, so that an even curve may result on the outside.

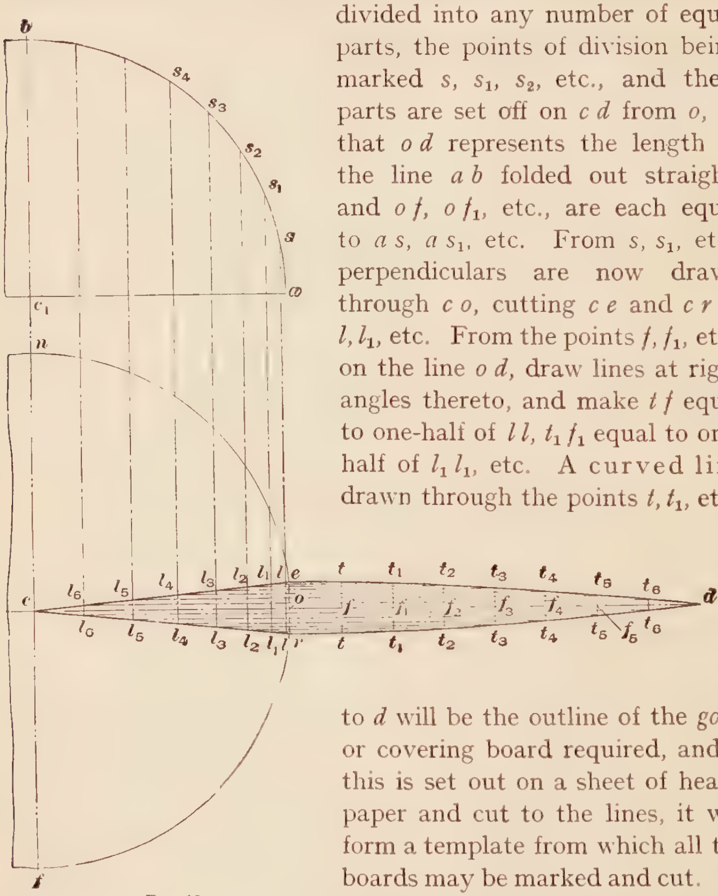


Fig. 19

A conical roof is boarded in the manner just described, and small purlins must also be framed in between the rafters to receive the boarding. The boarding of the conical roof, however, requires no curvature, but simply tapers from the plate toward the apex in a straight line.

29. The second method of covering a dome is shown in Fig. 20. The boards in this case are laid in short horizontal courses as at *f o b a*. The springing line of the dome is shown at *w a*. One-half the curve of the elevation *a e*, Fig. 20, is divided into any number of equal parts as *a b*, *b c*, *c d*, etc., each part being equal to the width of one of the covering boards. The line *b c* is drawn from the point *b* through the point *c* and is prolonged until it intersects the axis *f e* of the dome, prolonged, at *h*; then, from the point *c* through *d* a line is drawn until it intersects the axis line at *j*, and so with each of the other parts, until the points *k*, *l*, *m*, etc., on the axis line are obtained. With *h* as a centre and a radius *h b*, the curve that will form the lower edge *b q* of the board *b c* can now be described, while with the same centre and a radius *h c* it is possible to describe the arc *c p* that marks the curvature of the upper edge of the board. From the point *j* as a centre, and with the radii *j c* and *j d*, the arcs *c t* and *d u* are described; these mark the outline of the board *c d*. In the same manner the outline for each of the boards in the dome is marked, until the top opening, or eye, is reached, which, when not to be framed, is closed over with a flat circular piece of board, the centre of the curvature of which would be at *e*.

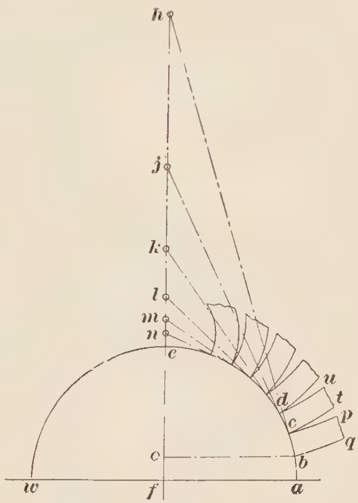


FIG. 20

30. When a dome is comparatively small and great neatness is required in the perfection of its semicircular outline, it is desirable that the joints should be planed down to round the surface, whether the boards run horizontally round the dome, as in Fig. 20, or extend from bottom to top, as in Fig. 19. When a dome is large and well above the eye, as on the roof of a high

building, such nicety is not required, as the covering material will round the form to the desired outline.

31. Interior Domes.—An **interior dome** is sometimes built under a flat roof, and is very commonly seen over a staircase that is illuminated through an ornamental glass ceiling light, inserted in the eye of the dome. These interior domes are

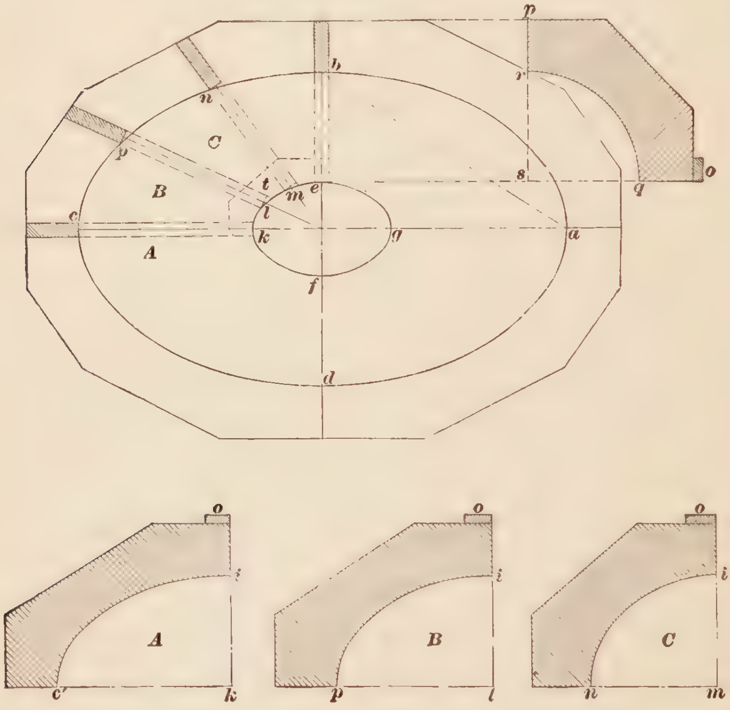


Fig. 21

generally elliptical in form, but, whether the outline is a semicircle or a semiellipse, the method of framing is precisely the same.

Fig. 21 shows the plan of an interior dome, the outline of which is an ellipse having a length *a c* and a width *b d*. In the centre is shown the eye, of which the length *k g* and width *e f* are in direct proportion to the length and breadth of the larger ellipse. The plane of the dome *a b c d* is formed by cutting

the curved sides from separate boards and nailing these boards round the opening framed in the floor or roof over which the dome is to be built. The eye of the dome is made of four or more pieces of board securely nailed together to receive the upper ends of the ribs when set in place.

There will be four sets of these ribs, each set representing one-quarter of the dome. The rib $b\,e$ will have for its curve a quarter circle with a radius $e\,b$, as shown at $o\,q\,r\,p$, where the points e and b have been projected to q and r, and the arc $r\,q$ has been struck from s as a centre, with a radius $s\,r$ equal to $e\,b$. The other ribs $k\,c$, $l\,p$, and $m\,n$ have each the curve of a quarter ellipse, the shorter semiaxis of which, in each case, is equal to the height of the rib $b\,e$, shown at $s\,q$; their larger semiaxis will be the length of each rib in plan, as $m\,n$, $l\,p$, and $k\,c$. These ribs are shown at A, B, and C, each of the vertical heights $k\,i$, $l\,i$, $m\,i$ being equal to $s\,q$; on each of them, at o, is shown the section of the eyepiece t that holds them in place. Such a dome as this should be lathed with wire lathing, as it is impossible to preserve the curvature with wooden laths.

32. Groined Ceilings.—A **groined ceiling** is formed by the intersection, or crossing, of two arched ceilings or passageways. The framing required for a ceiling of this kind is shown in Fig. 22, where A is an arched passage 3 feet 8 inches in width intersected by another arched passage B, 6 feet 4 inches in width. At $b\,f\,d$ is shown the soffit of the arch over A, revolved on the exterior line of the thickness of its material to keep it clear of the other details, and at $b\,g\,c$ is shown the soffit of the arch over B, revolved in a similar manner. The lines of intersection of these arched, or vaulted, surfaces are called *groins*, and they occur on the diagonals $a\,b$ and $c\,d$, which intersect at o. If both passages were of the same width, both arches could be semicircular, as is the arch over A; but as B is much wider, and at the same time no higher, than A, the curve of the arch over B becomes a semiellipse, with its longitudinal axis $b\,c$ equal to the width of the passage, and its semitransverse axis over the axial line of the passage B equal to the height $f\,q$ of the semicircular arch over A. The groins $a\,b$ and $c\,d$ will also be semiellipses. Their

curvature and the necessary dimensions for the ribs may be obtained by erecting *o n* perpendicular to *a b* and equal in length to *f q*, and then describing the quarter ellipse *b r′ m′ n*, with *o n* as its semiminor axis and *o b* as its semimajor axis. These semielliptical arcs may be described according to the method explained in *Geometrical Drawing*, or points on the curves may be determined by projection. From any points on the semi-

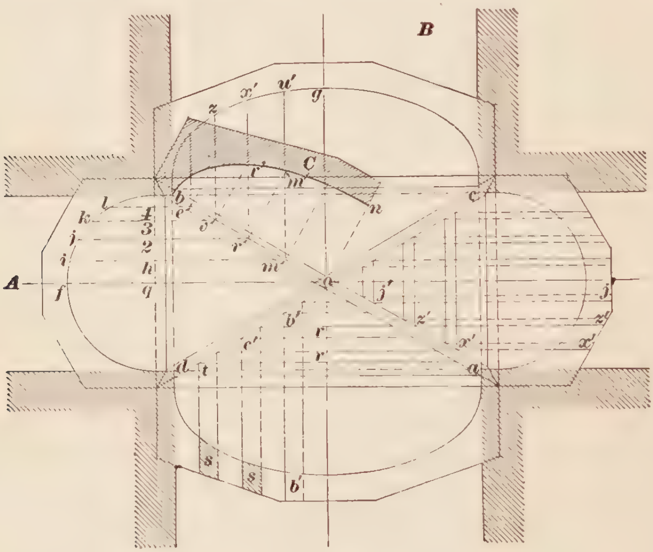


Fig. 22

circular arch, as *i*, *j*, *k*, *l*, draw the lines *i m*, *j r*, *k v*, *l e* parallel with *o f*, and where these lines intersect the diagonal line *o b*, erect perpendiculars both to the groin and to the line *b c*. Then, by setting off successively on these perpendiculars the distances *i h*, *j 2*, *k 3*, and *l 4*, from *m*, *r*, etc., on the line *ab* and the same distances from the line *b c*, points will be established through which may be drawn the curves *b n* and *b z g*.

Between these intersecting groin ribs, small jack-ribs, or rafters, *r* are framed, and their curved outline is precisely the same as that of the main ribs *b g c*, Fig. 22, as far as they reach on each side of the centre, or axial, lines. The main ribs and jack-ribs are spaced from the centre *o* at a uniform distance

of 16 or 24 inches, according to the span, and laths are then applied in the usual manner to the under side.

The lengths and cheek cuts of these jack-ribs may be determined by projecting their points of intersection with the groin ribs to the curve of the main ribs. Thus, from the points j', z', x' and b', c', t on the groin ribs $o\,a$ and $o\,d$, Fig. 22, draw the lines $j'\,j'$, $z'\,z'$, etc. The exterior lines of each rib will determine the length of the side of the jack-rib that is farther away from the point o, and the interior lines for each rib will mark the length of the jack-rib that is nearer the point o. Then, if these lines are marked on opposite sides of the jack-rib, a line connecting their ends across the edge of the jack-rib will mark the cheek cut, as shown for the two longer jack-ribs at s, s.

33. Pointed Arches.—A **pointed arch** is one composed of arcs struck from two or more centres, the curves of which are not tangent to each other, but meet at an angle, as shown at f, Fig. 23. The ceiling of two intersecting passages, which are vaulted in the form of a pointed arch, or vault, forms a groined vault not unlike that just described.

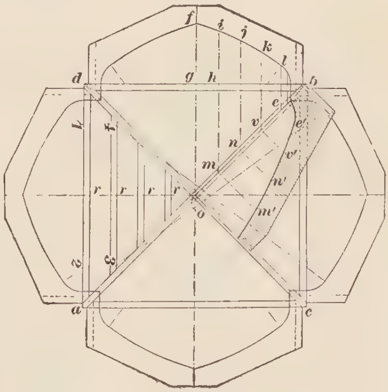


Fig. 23

34. Pointed Vaults.—The **pointed vault** shown in Fig. 23 is composed of the arcs of two circles described from four centres *1*, *2*, *3*, *4*, as shown by the radial lines. The smaller arcs at the sides of the vault, described from centres *1* and *2*, are tangent to the larger ones described from centres *3* and *4*; but the two arcs last named are not tangent to each other, and therefore form a point at the centre that is over the axial line of the passage. As explained in Art. **32**, the diagonal, or groin, ribs are set out by means of lines projected from points on one of the arches parallel with the axial line $f\,o$, and intersecting the groin line $a\,b$. Perpendicular to the groin

at these points of intersection, the lines $m\,m'$, $n\,n'$, $v\,v'$, and $e\,e'$ are drawn equal in length to $i\,h$, etc., respectively, and through the points m', n', v', e', the curve of the groin is described. The wooden rib, the under side of which forms the contour of this groin, is shown by the shaded portion.

Between these intersecting groin ribs small jack-ribs r are framed, and their curved outline is precisely the same as that of the main ribs $d\,f\,b$ as far as they reach on each side of the centre line. The main ribs and jack-ribs are spaced from the centre o at a uniform distance of 8, 16, or 24 inches, according to the span, and laths are then applied in the usual manner to the under side. The bevels for cutting the ends of the jack-ribs are found in the manner previously described.

35. Pendentives.—Another method of finishing the roof or ceiling over the intersection of two passageways is to construct over the crossing a hemispherical dome, when the passages are of the same width, and an elliptical dome when they are of different widths. The effect of this treatment is shown in Fig. 24, where the passage A intersects and crosses the passage B, and the sides of each one, prolonged by dotted lines, form the rectangle $a\,b\,c\,d$, which is the plan of their intersection.

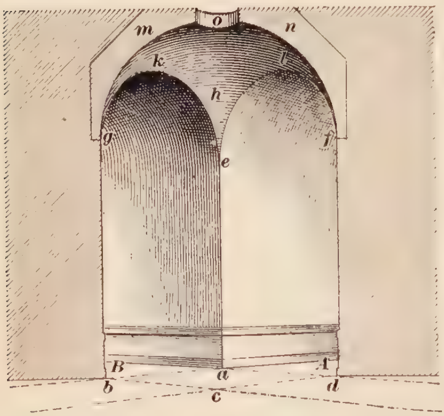


FIG. 24

The roof of each passage is vaulted over with a semicircular arch, as $g\,k\,e$ and $e\,l\,f$, while from the points e, f, and g, where these arches spring, there also starts a hemispherical dome $g\,m\,o\,n\,f$. The material at the corners e, f, and g gradually curves over to the eye of the dome at o, and broadens out in a fan shape over each of the adjacent arches, as at $e\,k\,l$. This spherical triangle $e\,k\,l$, which brings the curvature of the dome down to

the corner of the passage at e, is called a **pendentive,** and there is, of course, one of them over each of the corners a, b, c, and d.

36. To develop the curvature of the ribs and construct the framework for the dome and pendentives, the plan of the intersecting passages is first drawn, as shown at $a\,b\,c\,d$, Fig. 25. Next, the axial lines of the passages $A\;A$ and $B\;B$ and the diagonal lines of their intersection, over which the ribs $v'\,a'$, $g\,g'$, $a\,c$, and $b\,d$ are set out, are drawn. Then, with a centre o and a radius $o\,a$, draw a circle through the four corners of the plan $a\,b\,c\,d$; this circle will represent the plan of the dome. If this dome is now cut on the line $d\,c$ at right angles to its plan, the section on the vertical plane will be the semicircle $c\,e\,d$, which is the arch over passage A.

There will be four of these arch ribs, one over each of the lines $a\,b$, $a\,d$, $c\,b$, and $c\,d$, and that part of the dome which would extend into each of the passages, as at $a\,v\,d$, is cut off by the arches over the entrances to the passages A and B. Now, as the dome is a hemisphere, any section of it through the centre of its plan will be a semicircle, the radius of which is the same as that of the circular plan. Thus, the semicircle $b\,c\,d$ can be considered as a revolved section through the dome on the diagonal rib $b\,d$; $b\,c\,u\,y$ will then represent that rib as it would appear when cut out of its plank, with its lower end b resting on the corner, and its upper end c standing over the centre o a distance of $o\,c$ higher than the end b.

Four of these ribs will constitute the diagonals $a\,c$ and $b\,d$, and the jack-ribs, as $o\,g$, $o\,h$, $o\,i$, etc., will have the same curve exactly as far as they reach, but their upper ends will be bevelled and pointed to fit in round o, while their lower ends will require a plumb-cut and a cheek cut to fit them against the arch pieces at $a\,b$, $a\,d$, $c\,b$, and $c\,d$.

37. To find the lengths and cuts for these jack-ribs, from the points z and s, Fig. 25, where the sides of the ribs $o\,a'$ and $o\,b'$ intersect the side of the diagonal $o\,b$, draw $z\,u$ and $s\,t$ parallel with $o\,c$. The line $z\,u$, where it crosses the rib $b\,c\,u\,y$, will mark the shoulder from which to bevel the end of the rib $o\,a'$, and the line $s\,t$ will mark the shoulder from which to bevel the rib $o\,b'$.

The end piece *u c* will be cut off, as the rib *o b′* does not reach to the centre *o*.

Now, with *o* as a centre and the radii *o g′*, *o h′*, and *o x*, describe the arcs *g′ 1*, *h′ 2*, and *x 3*, which will measure the lengths of each side of these jack-ribs on the diagonal rib *o b*. The lines *1 l*, *2 m*, and *3 n* perpendicular to *o b* will cut the rib *b c u y* to the required lengths for the jack-rafters; *c u l k* will be the pattern for four of the jack-ribs *o g′*, *o a′*, *o g*, and *o v′*, the cheek cuts

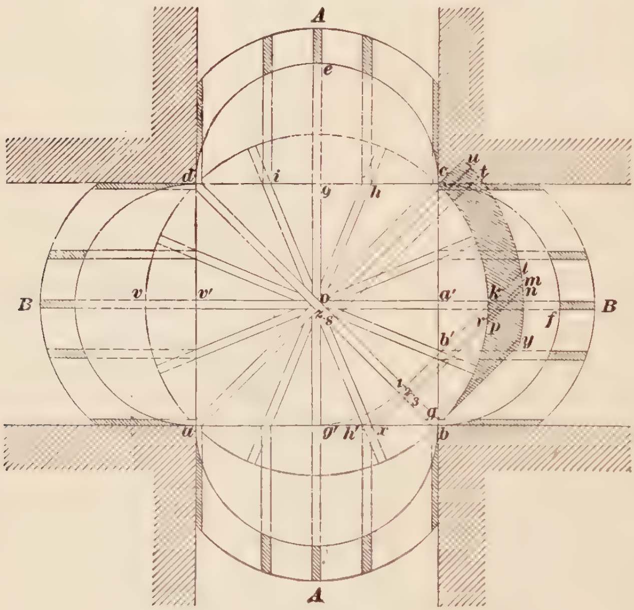


Fig. 25

being determined as just explained; and *c u n p* will be the pattern for the other jack-ribs, the plumb-cut of which, where they join the arch ribs *c e d*, *c f b*, etc., will be the line *p n* on one side of the rib and the line *r m* on the other side, while a line drawn on the top or bottom of the rib joining the ends of the plumb-cut lines will mark the cheek cut, or bevel.

38. In lathing the ribs of the passages, ordinary wooden laths may be used, but the pendentives and dome must have

metallic lathing, so that they may be smoothly finished in plaster.

39. Niches.—Vaulted, groined, and domed passages, such as those just described, seldom occur except in monumental work, in which case the side walls of the passages are often broken by niches for the reception of vases, pieces of statuary, etc. Fig. 26 shows the construction of such a niche. The plan (*a*) shows the base *a c b*, which is composed of $1\frac{1}{4}$-inch plank. Halved into the front edge of this base are the two studs *a* and *b*, shown in the elevation (*b*) at *a′* and *b′*, extending from the base to the head-piece *k*, to which they are nailed. The studs *n*, *o*, *p*, etc., extend from the base to the plate *l*, on which rest the curved ribs *n′*, *o′*, *p′*, giving the head of the niche a semi-domical form. The front is closed by two quarter-circle ribs *e f g* let in and nailed to the studs *a′* and *b′*. Bridging pieces, or stiffeners, *s* are inserted between the ribs, and the whole is then lathed with wire or other metallic lathing.

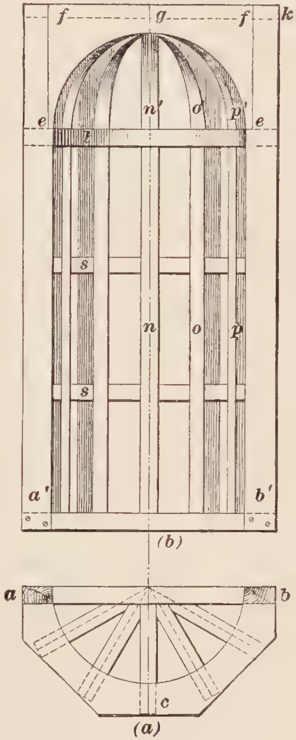


Fig. 26

BRIDGEWAYS

40. A problem that sometimes confronts a designer is a **covered elevated passage**, or **bridgeway**, connecting adjacent buildings. The treatment of its structural features should be in harmony with that employed in the building proper.

An example of a bridgeway is shown in Fig. 27. To relieve a horizontal beam line and the angularity at the wall connections, an arch rib is placed on each side, thus giving a pleasing outline

Fig. 27

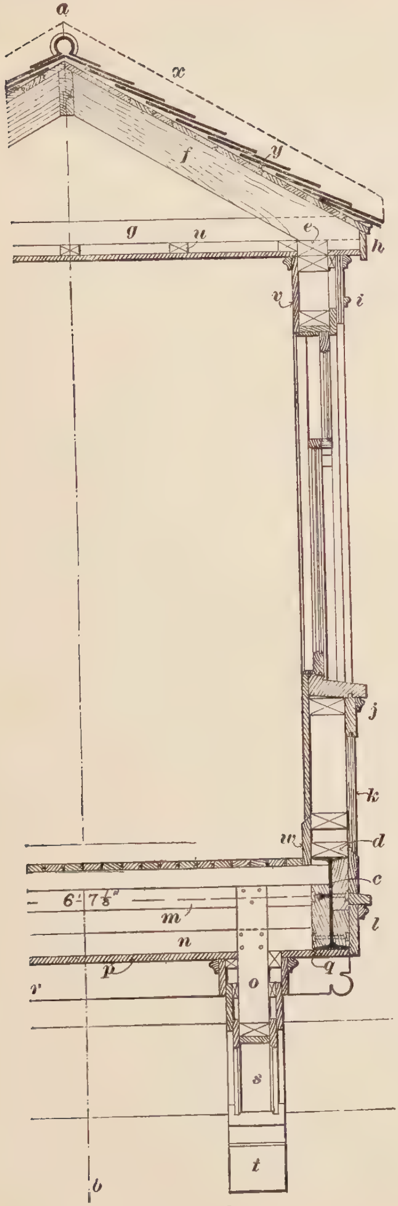


FIG. 23

to the soffit of the bridge. Corbelled springing blocks receive the end bearings of the arches and soften the appearance of an angle that would otherwise be disagreeable. These arches are kept well back of the lines of the bridge walls, and furnish an excellent opportunity to use a corbelled table as the base for the wall support, a characteristic of both buildings. This is effected by placing beams at right angles to the arches. These beams are 6 inches by 3 inches in section and have moulded ends. As the floor is required to sustain heavy moving loads, the arches are designed and constructed with reference to architectural effect only.

41. Steel joists *c*, Fig. 28, 15 inches deep, are used to span the space between the buildings and carry the weight of the superstructure. The walls are framed with sills *d*, plates *e*, and 6″ × 2″ studding. The roof is framed with rafters *f* and ties *g*, and is covered with narrow grooved and tongued or matched boarding $1\frac{1}{8}$ inches thick. The

cornice is cased, as at *h*, while at *i* is a frieze, or architrave mould. In an exposed situation, such a member should be tongued into the fascia to prevent water from lodging behind it. A framed and panelled dado *k* is placed between the sill-course *j* and the cap of the corbelled table, the upper rail being tongued into the window sill. The panels are made of $\frac{7}{8}$-inch narrow matched lining put together with white-lead joints, the framing being $1\frac{3}{8}$ inches thick and the lower rail bevelled to shed the water. Nailing cleats *m* are spiked to the 3-inch plank floor ; to these are nailed the hangers *o*, which serve both as supports and as blocking for the arch casings. Light ceiling joists are nailed to the hangers for the attachment of the ceiling lining *p* and soffit *q*. The lining is matched and beaded between the arches, and runs parallel thereto. The soffit *q* is one board, which, being devoid of longitudinal lines, renders the corbel lines more prominent.

42. The interior walls and ceiling are lined with $\frac{7}{8}$-inch narrow grooved-and-tongued or matched-and-beaded material *v*, the ceiling lining being fixed to longitudinal furring strips *u*. The bead lines on walls and ceiling are made to run in line. The wall lining is cut to finish on the jamb lines of the window frames, the openings being finished with a $\frac{5}{8}$-inch moulded sash stop, as shown. This treatment is lighter and simpler than that usually followed where a casing is planted on the surface of the lining. A continuous skirting *w*, $1\frac{1}{8}$ inches thick, is placed at the floor, and the upper edge is bevelled to receive the end of the vertical lining. By this arrangement, the beaded joints can be kept clean, a result unattainable when the lining is run down to the floor. Another objection to the extension of wall lining to the floor is that, when the floor is washed, more or less of the water is absorbed by the end wood, causing it to rot. The plank flooring, being run at right angles to the steel joists, is spiked to a plank bolted to these joists, while the finished flooring is laid diagonally, thus securing the greatest strength from the material employed. Quartered, or rift-sawn, flooring is used, so that under the wear of heavy truck wheels the fibres will not curl up and flake off.

43. The roof boarding is overlaid with heavy felt and is covered with terra-cotta tiles, the lap-jointed ridges being set in slater's cement. A flat gutter $\frac{7}{8}$ inch deep and 4 inches wide is formed at the wall junctions, in order to avoid tilting the edges of the tiles. The gutter flashing of 6-pound lead passes up 4 inches on the face of the wall and is beaded and inserted 1 inch into a raglet, or groove, left in the joint between the lower brick filling and the upper stone ashlar.

FLAGSTAFFS

44. Strange as it may seem, it is necessary to profile a flagstaff as carefully as if it were an architectural column. The curve of the shaft of a column is called the **entasis,** and the method of profiling this curve is also of service to the flagstaff designer. Two converging straight lines in any elevated structure have always the appearance of concavity, giving a weakened effect to the outline of the mass. Although, too often, no thought is given to these considerations, they should in all first-class work be carefully studied when designing.

In cases of flagstaffs extending from 30 to 60 feet above the highest point of the roof, the following rule has been found to give satisfactory dimensions :

Rule.—*The diameter, at the base of a flagstaff, where it passes through the roof, should be about one-fiftieth of the altitude, and the diameter at the apex should be equal to one-half of the lower diameter.*

For example, if a flagstaff is to be 41 feet 8 inches, or 500 inches, in length, its diameter should be one-fiftieth of this amount, or 10 inches, while its diameter at the apex should be 5 inches. The diameter at the base and the apex having been determined, it will then be necessary to profile the shaft by some accepted rule.

The method followed by the best mast makers is as follows : Make the upper diameter equal to one-half of the lower. Draw a centre line *a d* through the shaft, as shown in Fig. 29.

Divide $c\,d$, the lower semidiameter, as follows: From d mark a point equal to one-fourth of the lower diameter, as $d\,e$. Divide the remaining distance $e\,c$ into two equal parts, as at f, and divide the distance $c\,f$ into two equal parts, as at g, and the distance $c\,g$ into two equal parts, as at h. Divide the vertical height of the shaft into four equal parts by horizontal lines; transfer the distance $d\,e$ to $d_1\,e_1$, $d\,f$ to $d_2\,f_1$, $d\,g$ to $d_3\,g_1$, and $d\,h$ to $d_4\,h_1$. Then through the points marked will pass the curve of the entasis.

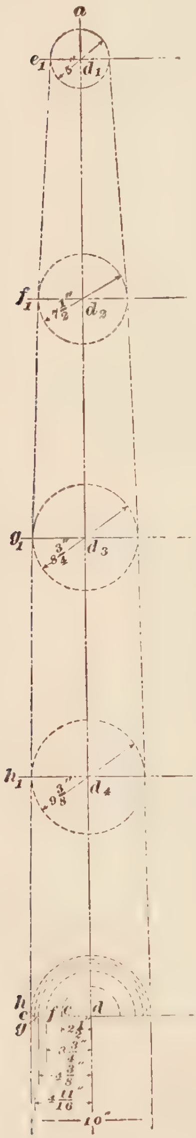


FIG. 29

45. In Fig. 30 are shown the metallic finial at the top of a shaft and the flashing to make the pole water-tight where it passes through the roof of a cupola. These parts are drawn to an enlarged scale, such as would occur in the working detail drawings. The ball a, in Fig. 30 (a), is 10 inches in diameter, of soft-rolled copper, spun down to about 18 ounces per superficial foot, and is sweated to the socket b. The stem c is a bronze tube $1\frac{1}{2}$ inches in diameter, while the cap d is of cast bronze. The stem c is threaded, and passes into the socket b and cap d, as shown in (c). The cover e protects the upper end of the pole and prevents water from passing into the fibre tubes. The flange f, being tightly fitted to the pole, keeps the stem of the finial in a vertical position, while heavy brass screws attach the lower flange g to the pole. An eyebolt l is secured to the cap, and is firmly held in position with a nut and locknut. The end of the eyebolt is also riveted in place. From the eyebolt is suspended a block, of brass or other metal, having a 3-inch brass pulley and pin.

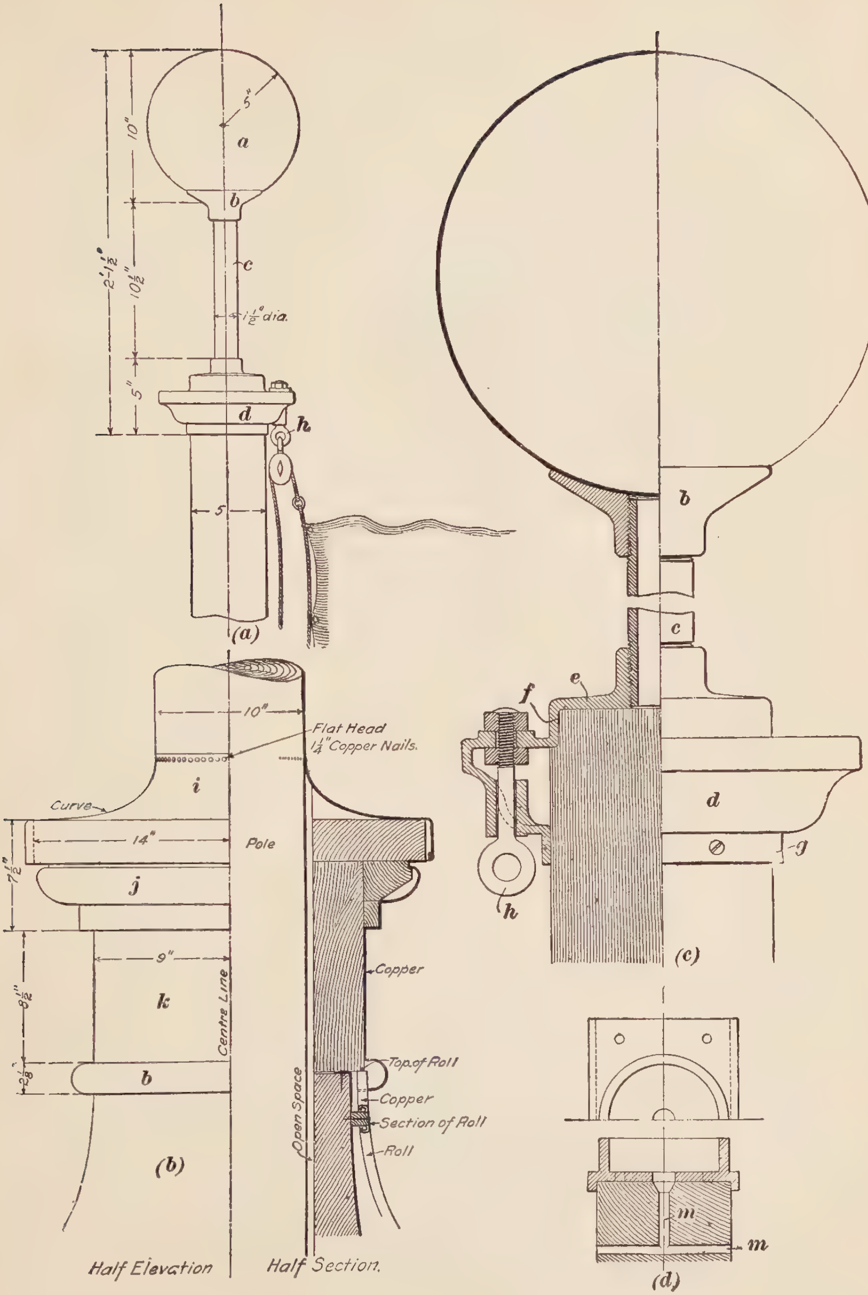

5"
10"
a
b
c
2'-1½"
10½"
1½" dia.
5"
d
h
5
(a)
10"
Flat Head
1¼" Copper Nails.
i
Curve
14"
Pole
7½"
j
9"
k
8½"
Centre Line
2⅛
b
Copper
Top of Roll
Copper
Section of Roll
Roll
Open Space
(b)
Half Elevation
Half Section.
b
c
e
f
d
g
h
(c)
m
m
(d)

FIG. 30

The pulley block is attached to the eyebolt with a detachable link, as shown in Fig. 31. This link is rigidly clasped by a bronze bolt to the eyebolt *h*, Fig. 30 (*c*). The link, being set at an angle, prevents the pulley block from swinging and chafing the flagstaff.

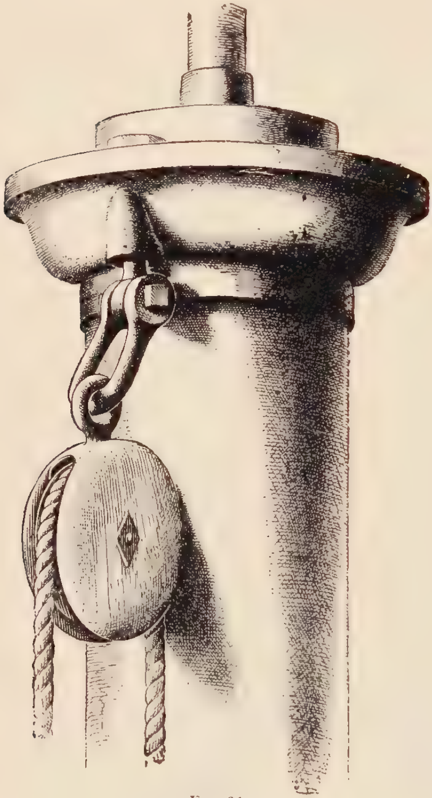


Fig. 31

In Fig. 30 (*b*) is shown a half-section of the apex of the dome of the cupola, through which the flagstaff passes. At *i* is a capped flashing of 8-pound lead, arranged in such a manner that the pole may sway without straining the connection. The bed mould, frieze, and collar band, as at *j*, *k*, and *b*, respectively, are of cold-rolled copper, as are also the roll caps of the dome. The panels of the dome between the rolls are of soft-rolled copper, which is sufficiently flexible to obtain the desired curvature.

In Fig. 30 (*d*) is shown a half-plan and section of a cast-iron socket plate, in which rests the base of the flagstaff. In order that any sap precipitated from the body of the pole may not be confined in the socket, causing fermentation and subsequent decay of the wood, a hole is formed in the plate, and 1-inch vertical and transverse holes, as at *m*, *m*, are bored through the beam, on which rests the flagstaff.

46. Flagstaffs may be constructed of spruce, Norway pine, pitch pine, or Oregon pine. The last is considered to be

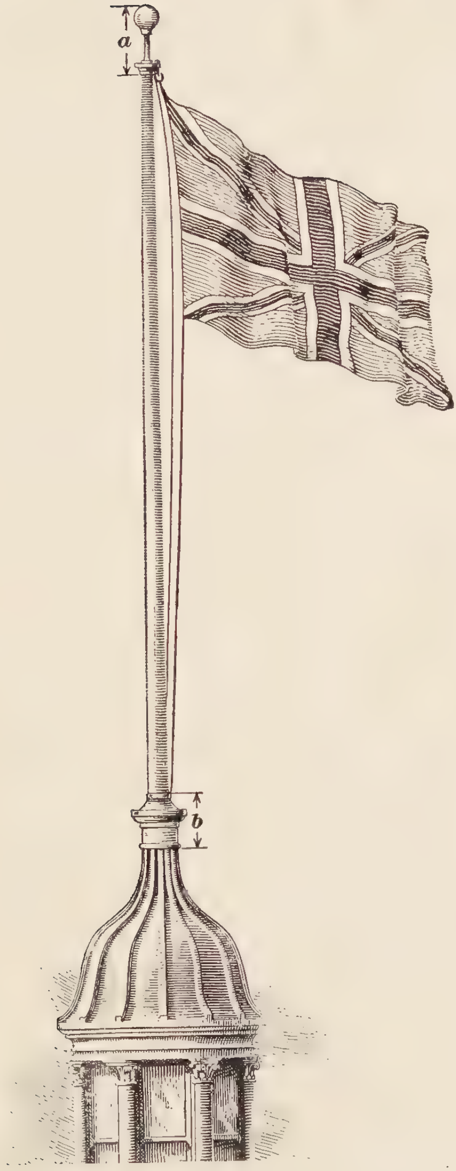


FIG. 32

preferable, and, where the entire sapwood is removed by cutting the flagstaff out of the heart of a large trunk, a durable pole is obtained. The pole should be painted with at least four coats of genuine white lead. The ball of the finial should be prepared with oil size and then gilded with gold leaf.

Halyards should be at least $\frac{1}{2}$ inch in diameter, and be of waterproof braided cotton or, preferably, Italian hemp.

The appearance of a flagstaff made according to the drawings shown in Figs. 29 and 30 is shown in Fig. 32.

FRAMING A HAY BARN

47. In the construction of *mansard* or *gambrel-roof* hay barns, where it is desired to leave a wide central space so that the wagon may be drawn into the barn and unloaded, or loaded from the mow on each side, the following two systems of framing will be found to meet the requirements in barns about 34 feet in width. The mansard form of roof is used because it gives a large interior area.

48. In Fig. 33, timbers *d*, *g*, *f* are set on the sill *h*; these timbers support the plates at *g* and *b*. The floor joists are spiked to the toe of the timbers at *h*, and as these joists reach across the building, they effectively tie the toes together. Considering the frame formed by the pieces *c*, *d*, *e*, *f*, *g*, as hinged at *b* and *h*, it is evident that the thrust *b*, caused by the rafters *i*, *i* tending to straighten out under the vertical load, will revolve and cause the frame or members *c*, *d*, *e*, *f*, *g* to turn outwards about the point *h*.

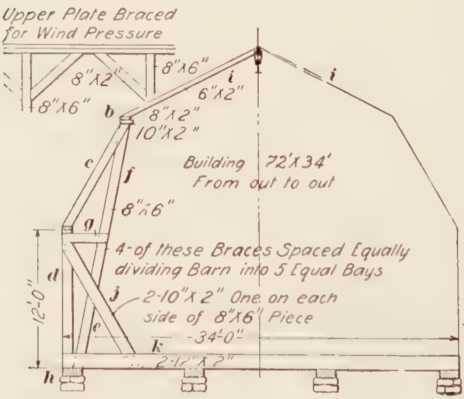


Fig. 33

This frame must therefore be held in position, and to do this the brace *j* must be introduced. The force in this brace will be tensile, which will exert an upward pull on the joist *k*. This force will tend to produce bending in the joists, but the weight of the flooring and load will more than counteract this tendency, as will also the weight of the roof on the rafters *c*.

49. Another and more stable form of construction is shown in Fig. 34. Here, a post *b* stands vertically and directly supports

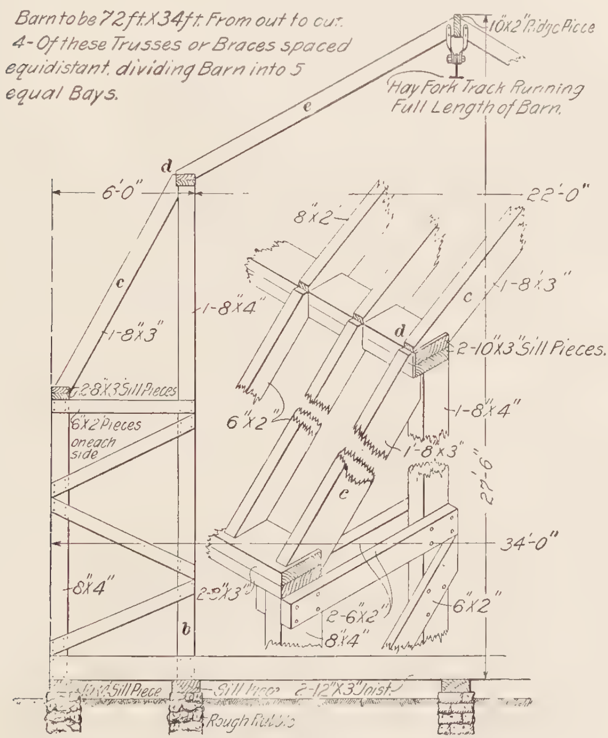


FIG. 34

the plate *d*, on which rest the rafters *e*. The posts are tied and braced, as shown, and are also held together by the floor joists. The frames or trusses are six in number, including those at the

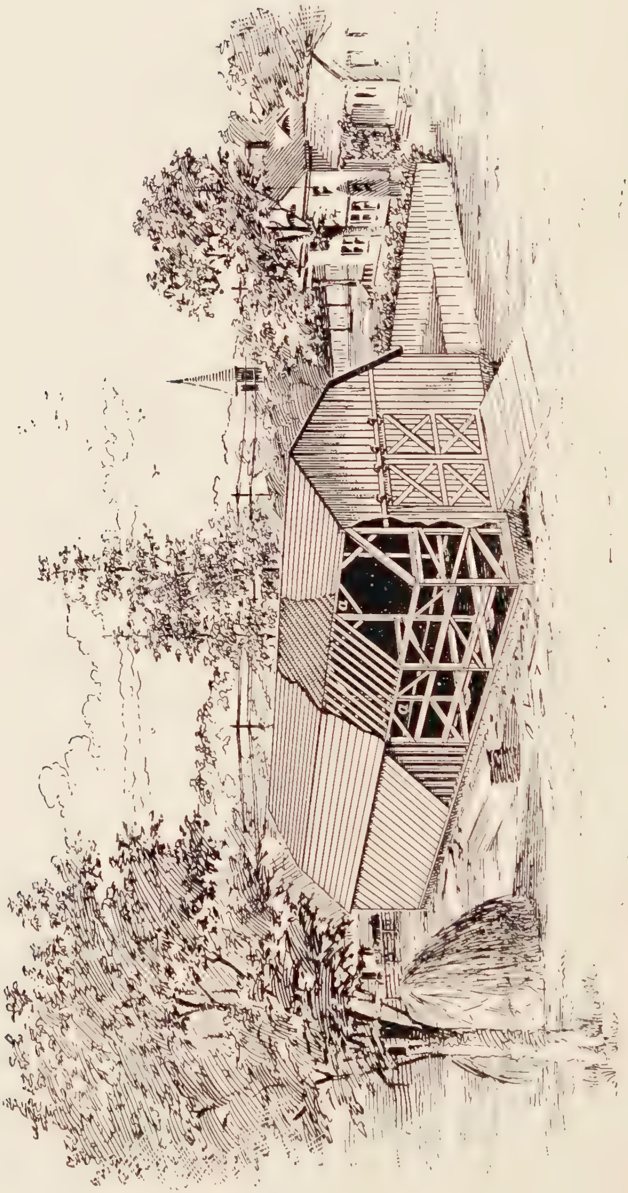


Fig. 35

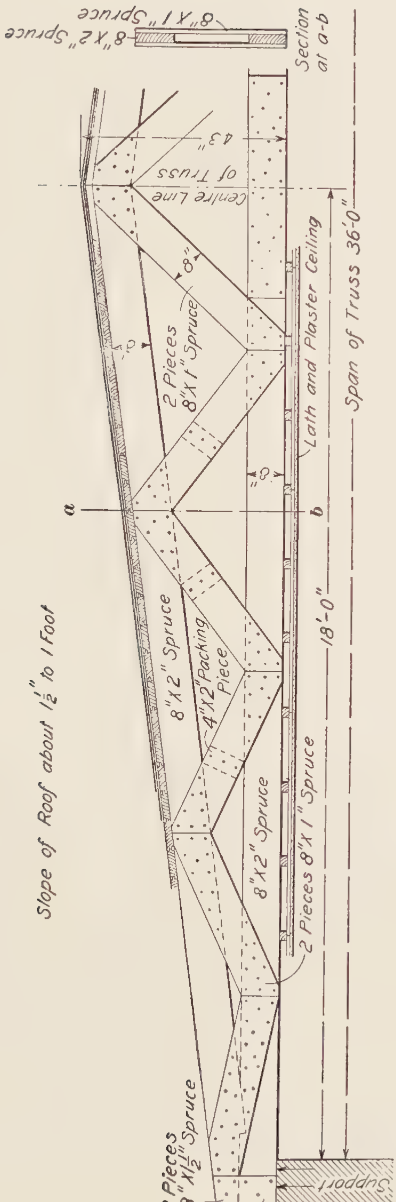


FIG. 36

end, and are spaced about 14 feet 5 inches apart from centre to centre.

The gable ends can be constructed as shown in Fig. 35 or with a tie or collar beam. In the latter case the construction shown in Fig. 34 need not be followed at these points. The sills are continuous the full length of the building, and, in addition to supporting the upright posts of the framing, they form a bearing for the floor joists. The ends of the rafters shown in Fig. 34 are notched and fitted to the upper and lower roof plates, thus making the work secure at these places and eliminating all danger of the rafters slipping or pushing outwards under direct compressive stress. The edges of the rafters *c*, *c* should be somewhat above the edge *d* of the plate, so that, should the rafters shrink considerably, the roof boarding will still have a bearing on them and not on the edge *d* of the plate. Longitudinal bracing should be introduced to

stiffen the frame, as shown at *a, a,* Fig. 35. If the sides of the barn are shingled or weather boarded, these braces can be done away with entirely by running the boarding diagonally, thus adopting the balloon-frame type of construction.

LATTICE BRACING

50. Fig. 36 shows in detail a system of trussing, or bracing, the rafters in conjunction with the ceiling joists for a roof having a long span and a low pitch. The rafters and joists are to be 8 inches by 2 inches, and of a good quality of spruce or pine. The lattice braces are composed of $8'' \times 1''$ timbers, and are placed in pairs, one on each side of the main members, to which they are spiked. The spiking, or nailing, should be well done, especially in the lattice members near the supports of the rafters, as the greatest stress is on these members. It will be necessary to splice the tie-member at the centre of the span, as difficulty may be experienced in obtaining a piece 8 inches by 2 inches of sufficient length. For securing the splice, two fish-plates of 8 inches by 1 inch are used ; these are well spiked on each side of the $8'' \times 2''$ ceiling joists. Two iron dogs, well driven in, should be used to further secure the splice. The roof should be covered with $6'' \times 1\frac{1}{4}''$ tongued-and-grooved boarding, on which the lead or other sheet-metal covering is laid. Battens for the lath and plaster of the ceiling should be placed at 14-inch centres As all the necessary details of construction are shown in the figure further explanation is not required.

HALF-TIMBER WORK

51. Figs. 37 to 39 illustrate a very picturesque method of wall construction, called **half-timber work.** This method was very popular throughout mediæval Europe, and many beautiful and interesting structures of the type are still extant, attesting the skill and taste of our ancestors. Figs. 37 to 39 are three different views of the Leicester Hospital, at Warwick, dating from the days of Queen Elizabeth. This is probably as good an example of old half-timber work as can be found.

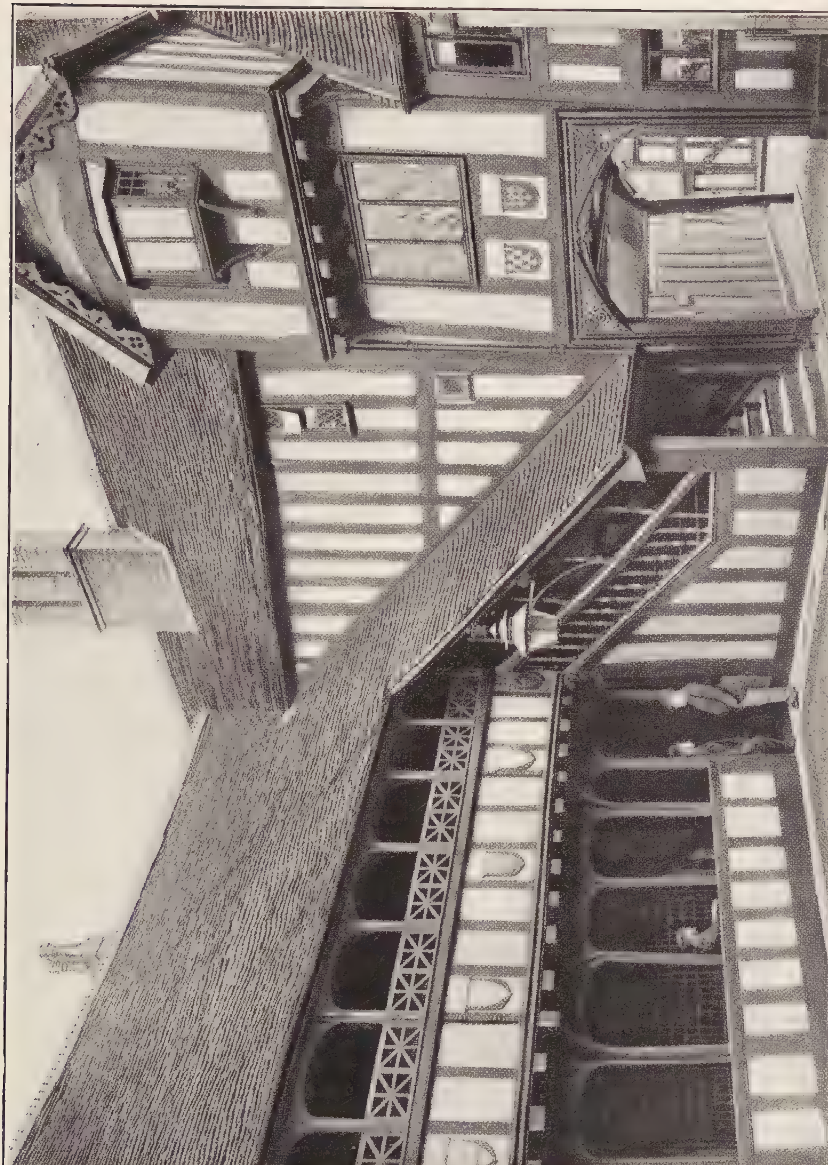


Fig. 37

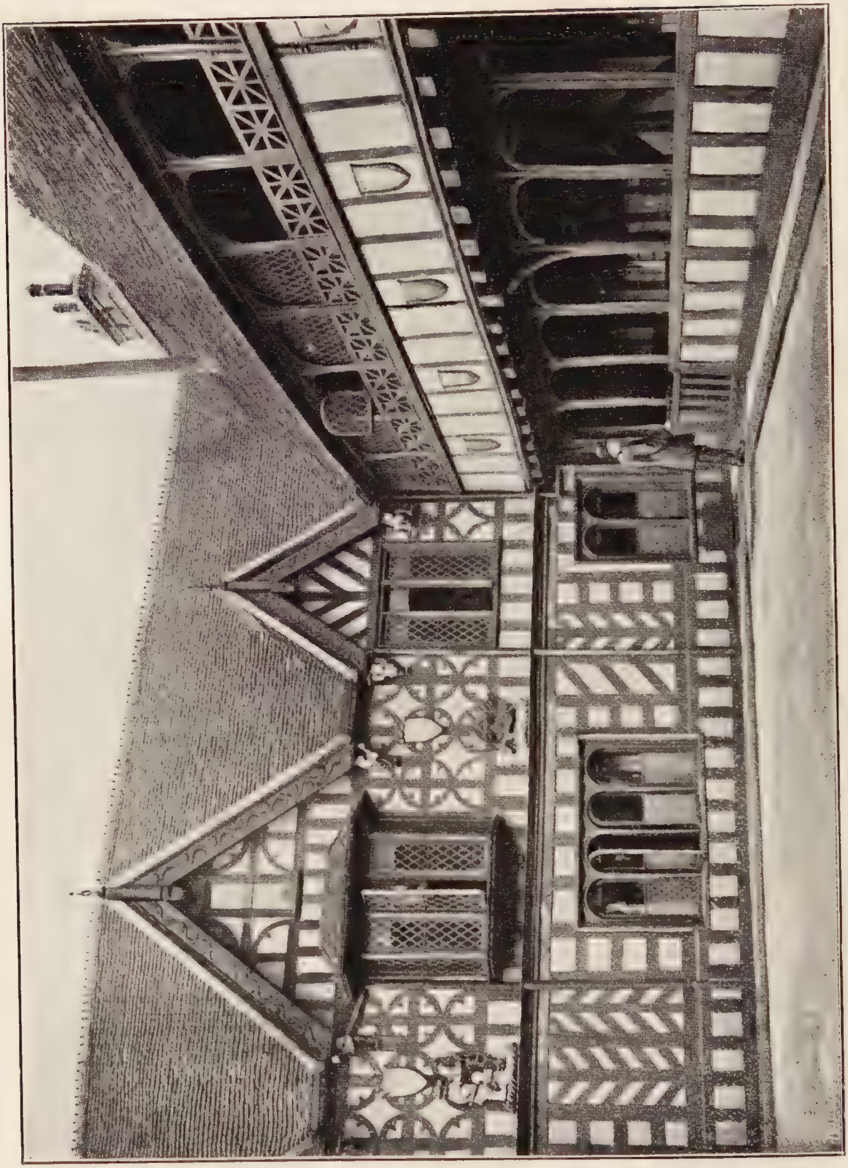


FIG. 38

Fig 39

In this work the timber of the exterior walls was structural, as in barn-framing, and of course ran right through the wall, the spaces between the timbers being filled with brickwork, on the outer surface of which was placed one or more coats of plaster, finished smooth or rough-cast. The inner surface was lathed and plastered in the usual way.

Recourse to **half-timber work** should be restricted as far as possible to buildings which will admit of the construction being carried out in a truthful manner. The introduction of anything in the nature of sham work is to be deprecated by all interested in good architecture.

The method shown in Figs. 37 to 39 of making the timbers constructional is the correct one, but imitation half-timber work is often erected.

52. In Fig. 40 is illustrated a method of construction often used in imitation half-timber work. At (*a*) is shown the plan of a corner post of a building and a method of constructing the intermediate portions of the framing. The corner post *a* has to be set up, and studs *b* are placed at intervals of about 18 inches from centre to centre, on the face of the studs being fixed the exposed timbers *c*. These are usually about 2 inches thick, and from 8 to 10 inches wide on face. Fillets *d*, *d* are nailed to the sides of the timbers *c* and the post *a* to receive the lathing and plastering *e* on the exterior face.

To give a good key and prevent the plaster from falling off, the posts and timbers are often grooved as shown at *f*. The plastering here is shown to finish about $\frac{1}{8}$ or $\frac{1}{4}$ inch back from the face of the timbers, giving a good effect. On the inside face the lathing and plastering *h* is finished across the studs as in an ordinary framed partition, and the corner next the posts is finished by nailing fillets *g*, *g* to the post *a*.

Fig. 40 (*b*) illustrates another method of constructing imitation half-timber work, the studs being shown at *a*, the exposed face timbers at *b*, the external lathing and plastering at *c*, and the fillets to which the lathing is fixed at *d*. The space *e e* between the studs is filled in with brickwork, when the partition is said to be *brick nogged*.

On the inside face of the brickwork furring strips *g*, *g* are often fixed, to give a fixing for the lathing and plastering *h*. In many cases the plastering is laid direct on to the brick nogging.

In Fig. 40 (*c*) is shown a section through an overhanging story, or oriel window, in imitation half-timber work. At *a* is

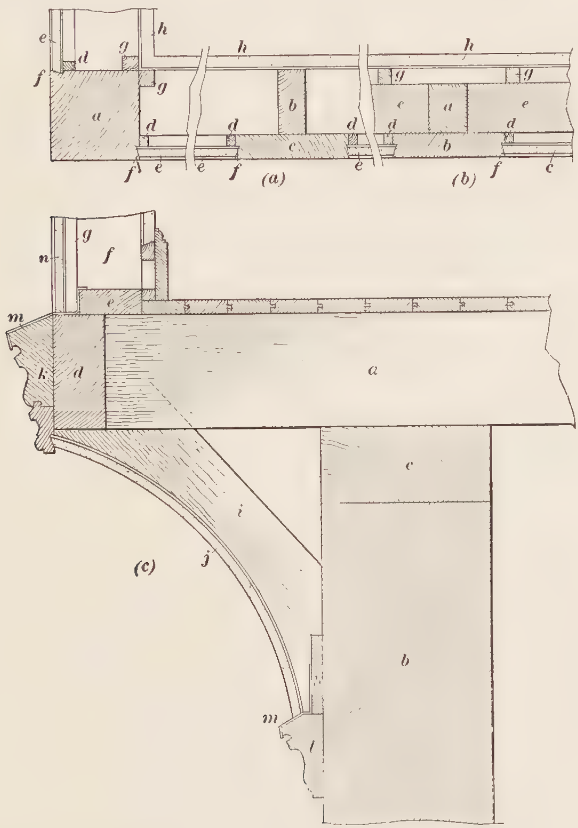


Fig. 40

shown the timber floor joists projecting over the wall *b* and resting on the stone template *c*. The joists *a* act as cantilevers and are trimmed at their ends into the joist *d*. On top of the joists is fixed a plate, or runner, *e*, which receives the studs *f* of the half-timber framing, on the face of which are fixed the face

Fig. 41

timbers *g* which receive the lathing and plastering *n* in a similar manner to that described in connection with Fig. 40 (*a*) and (*b*).

The finish of the cove under the floor joists is made by securely spiking to the wall *b* a rough nailing board *h*, on which rest the rough shaped brackets *i*. These rough brackets are securely

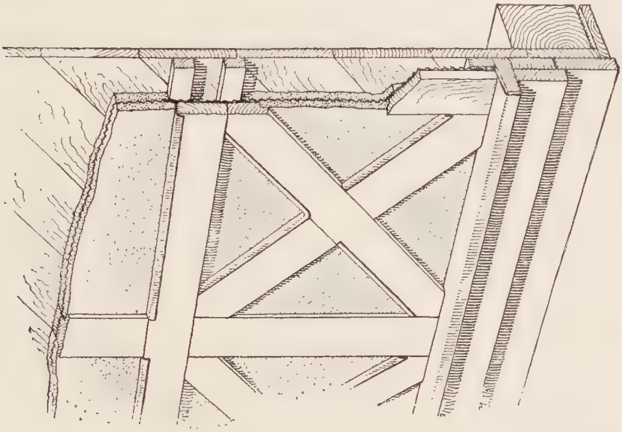


Fig. 43

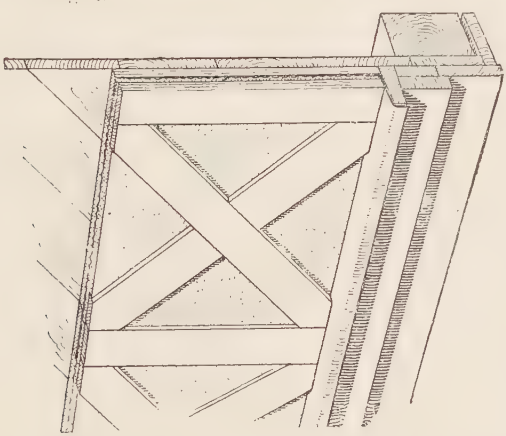


Fig. 42

nailed to the board *h* and to the sides of the joists *a*, and are finished on their face with lathing and plastering *j*. A capping moulding *k* is fixed to the trimmer *d* and another moulding *l* on the face of the wall at the bottom of the cove. To prevent water from penetrating the woodwork and causing decay, lead

flashing is dressed over the wood mouldings and under the back of the lathing and plastering, as shown at *m*.

53. Fig. 41 shows a design for a cottage, typical of the earlier work, but constructed on a cheaper scale. The ground-floor

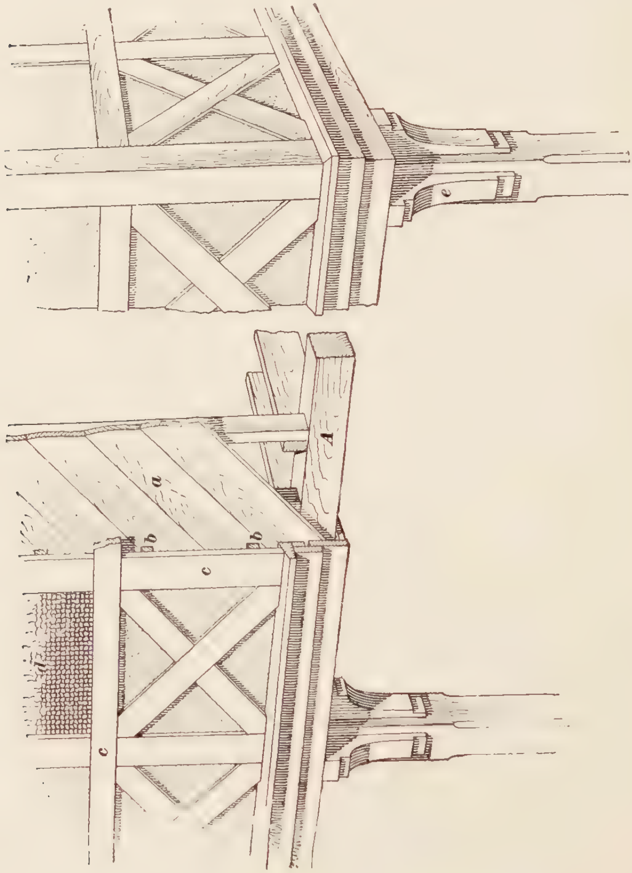


Fig. 44

story is constructed with common bricks, covered with a coat of plaster having a "slap-dash" or rough-cast finishing coat. The upper walls are constructed in a manner similar to that described in Art. **52**.

54. In Figs. 42 and 43 are shown details of two methods of constructing the half-timber work over the porch. Probably that shown in Fig. 42 (here the first or first two coats are placed before the battens are fastened, followed by the last coat) would be the tighter, as the opening of the joint between the plaster and the timber is less liable to result in the penetration of water into the wall behind than in the construction shown in Fig. 43. If it is possible to delay the work to such an extent, this timber work, after being put in place, should be allowed to stand several

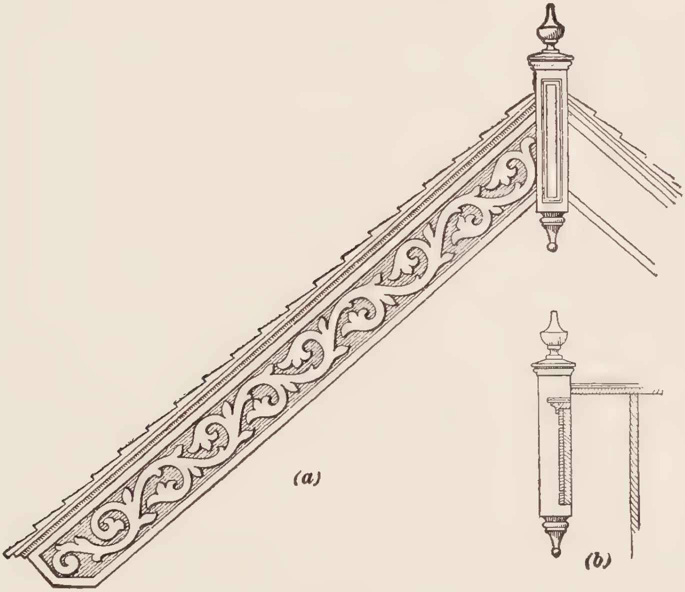


Fig. 45

months before the plaster is applied. By doing this, the greater part of the shrinkage in the half-timber work will have taken place by the time the plastering is done, and the opening of the joint will be reduced to a minimum. An addition to the cement mortar of a proportion of lime putty will make it more plastic and elastic.

When metal lathing is used, a waterproof coating should be applied to the plaster to prevent the corrosion of the metal caused by the penetration of rain-water.

FIG. 46

55. Fig. 44 shows the general construction of the work over the porch. The brackets *e* are housed into the posts. The beam *A* carries the floor joists and frame wall ; *a* is the sheathing, to which the furring strips *b* are attached, and *c*, *c* are the battens or casings. The barge board of the gable is shown in Fig. 45, in elevation at (*a*) and in section at (*b*). In this case the ornament is carved out of yellow pine, bedded in thick white-lead paint, and nailed to the face of the barge board. In many cases a pattern is formed by piercing this board, instead of applying the ornament as in this instance.

56. A number of old half-timber-work houses, still standing in the heart of London, are illustrated in Fig. 46. They were erected about the year 1625, and are now used as business premises.

THE STEEL SQUARE

PRINCIPLES OF APPLICATION

DESCRIPTION OF THE SQUARE

57. A tool much used by mechanics in America and the Colonies is the **steel square,** and although it is not much seen in the British Isles, its usefulness is so great and its application so varied that a short description of its markings and uses is here given. Notwithstanding the mass of marks and figures on it, there is nothing about a steel square that is complicated or that requires a knowledge of higher mathematics to enable it to be used in ordinary practice, for after a few hours of careful study and examination, every mark and figure should be clearly understood. There are many ways of marking the square, the method adopted depending on the design or type and the purpose for which it is to be used. These markings, however, in no way affect the principles of application, so that when these principles are once thoroughly understood, any make of square can be accurately used, provided, of course, that the instrument is true.

58. Parts of a Square.—The long arm of a square is called

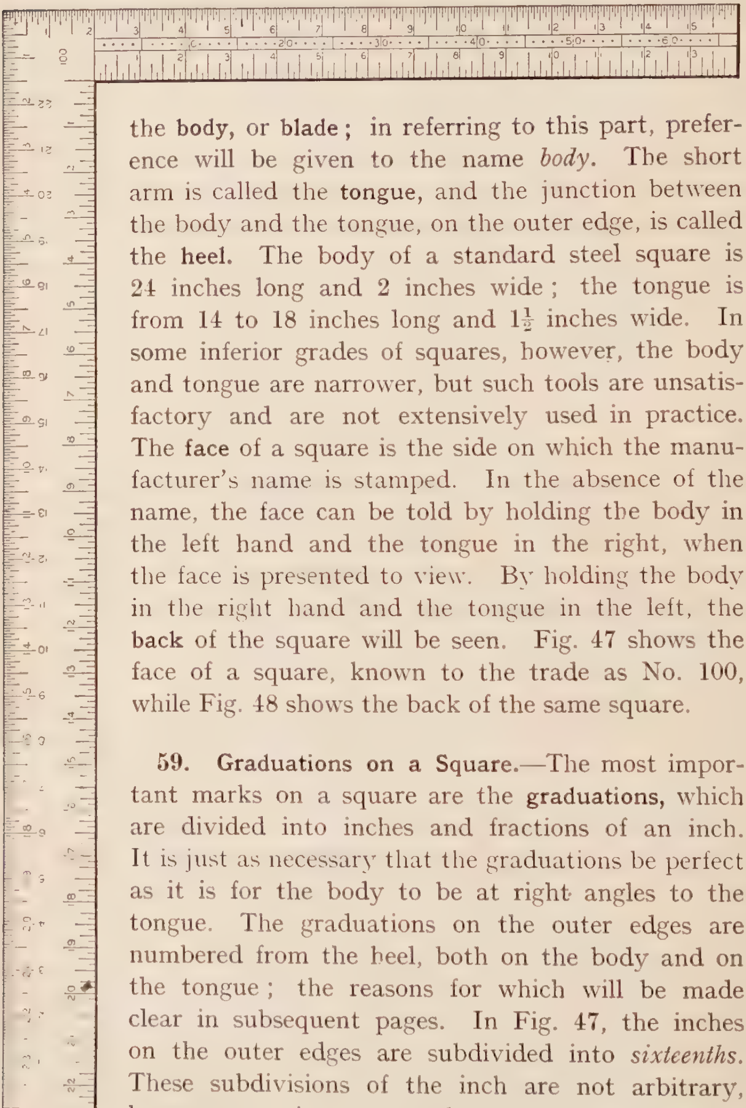


Fig. 47

the **body, or blade**; in referring to this part, preference will be given to the name *body*. The short arm is called the **tongue**, and the junction between the body and the tongue, on the outer edge, is called the **heel**. The body of a standard steel square is 24 inches long and 2 inches wide; the tongue is from 14 to 18 inches long and $1\frac{1}{2}$ inches wide. In some inferior grades of squares, however, the body and tongue are narrower, but such tools are unsatisfactory and are not extensively used in practice. The **face** of a square is the side on which the manufacturer's name is stamped. In the absence of the name, the face can be told by holding the body in the left hand and the tongue in the right, when the face is presented to view. By holding the body in the right hand and the tongue in the left, the **back** of the square will be seen. Fig. 47 shows the face of a square, known to the trade as No. 100, while Fig. 48 shows the back of the same square.

59. Graduations on a Square.—The most important marks on a square are the **graduations**, which are divided into inches and fractions of an inch. It is just as necessary that the graduations be perfect as it is for the body to be at right angles to the tongue. The graduations on the outer edges are numbered from the heel, both on the body and on the tongue; the reasons for which will be made clear in subsequent pages. In Fig. 47, the inches on the outer edges are subdivided into *sixteenths*. These subdivisions of the inch are not arbitrary, however, as the same maker may employ several methods for subdividing the inch, not only on the face,

but also on the back of the square. The inch marks along the

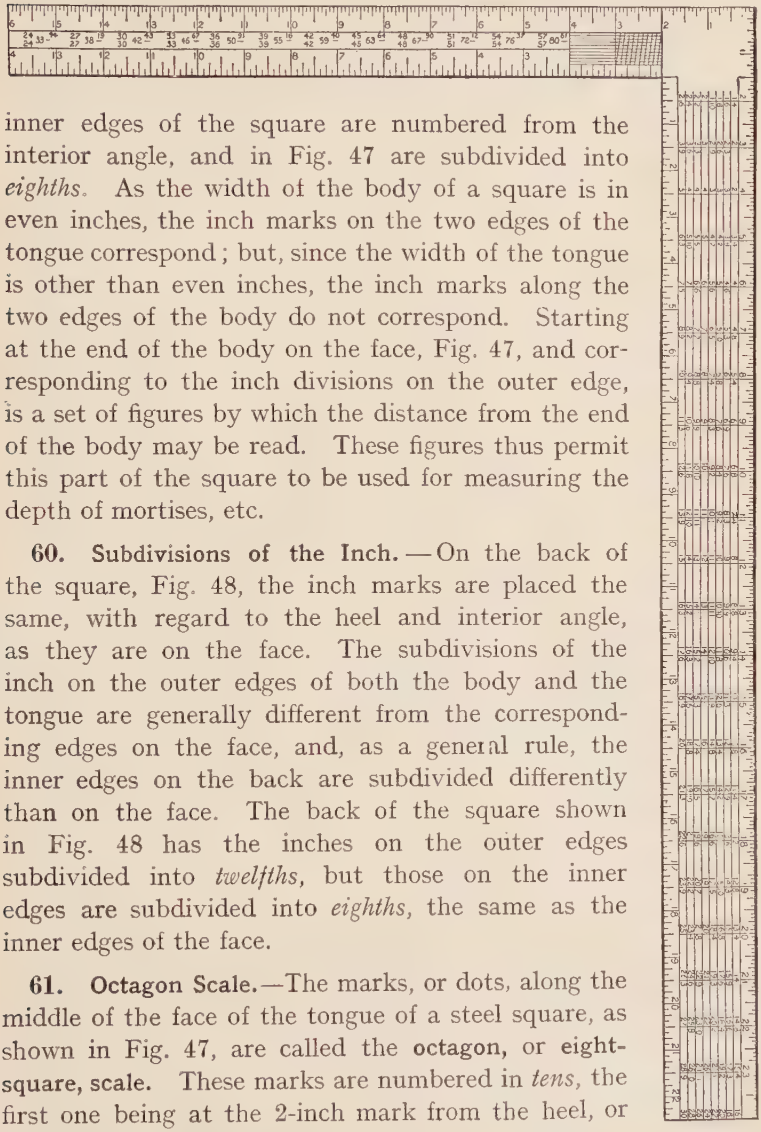


Fig. 48

inner edges of the square are numbered from the interior angle, and in Fig. 47 are subdivided into *eighths*. As the width of the body of a square is in even inches, the inch marks on the two edges of the tongue correspond; but, since the width of the tongue is other than even inches, the inch marks along the two edges of the body do not correspond. Starting at the end of the body on the face, Fig. 47, and corresponding to the inch divisions on the outer edge, is a set of figures by which the distance from the end of the body may be read. These figures thus permit this part of the square to be used for measuring the depth of mortises, etc.

60. Subdivisions of the Inch.—On the back of the square, Fig. 48, the inch marks are placed the same, with regard to the heel and interior angle, as they are on the face. The subdivisions of the inch on the outer edges of both the body and the tongue are generally different from the corresponding edges on the face, and, as a general rule, the inner edges on the back are subdivided differently than on the face. The back of the square shown in Fig. 48 has the inches on the outer edges subdivided into *twelfths*, but those on the inner edges are subdivided into *eighths*, the same as the inner edges of the face.

61. Octagon Scale.—The marks, or dots, along the middle of the face of the tongue of a steel square, as shown in Fig. 47, are called the **octagon, or eight-square, scale.** These marks are numbered in *tens*, the first one being at the 2-inch mark from the heel, or where the tongue joins the body.

62. Other scales will be found on the face and back of many steel squares, such as the **diagonal scale,** as shown in Fig. 48 by the parallel lines on the back of the tongue near the junction with the body. This scale is used for measuring to more minute divisions than the primary divisions of a scale. The **brace scale,** shown by the numbers on the middle of the back of the tongue of a steel square. The equal numbers placed over one another represent the *run,* or the two sides of a right triangle, while the numbers at the right represent, in inches and hundredths of an inch, the length of the third side or hypotenuse. The scale for **board measure** is often found on the back of the body of a square, but this will only apply to America and the Colonies where timber is sold by this measure. In some of the latest designs of steel squares, the board measure is replaced by **rafter tables.** These tables are very convenient, and in roof framing are much more useful than the board-measure scale, as the cuts for the various members of a roof may be read direct from the scale.

APPLICATION OF THE SQUARE

63. While the octagon scale, diagonal scale, brace scale, and board measure on a square are very convenient, they are not absolutely necessary. After one is thoroughly conversant with the principles underlying the use of the steel square, these scales will be found of little use, for there is not a single framing problem likely to arise in practice that cannot be solved by means of an ordinary steel square that has only the graduations marked on the edges, provided the graduations are true and the body and tongue are at right angles to each other. The method of solving some of these problems will be explained, but the importance of having a square true cannot be overestimated. Although the steel square is particularly adapted for roof framing and is probably used more for that kind of work than for any other purpose, it has many other uses. The mechanic who thoroughly understands the principle of the steel square will continually find new problems that can be solved with greater ease by its use than by any other method; therefore, a few of the uses to which the square may be put will be explained.

SETTING OUT GEOMETRICAL FIGURES

64. Setting Out an Equilateral Triangle.—In Fig. 49 is shown a method of finding the angle of the sides and also the mitre angle of an **equilateral triangular** figure, that is, one which has all its sides equal in length and its angles containing the same number of degrees. The line *A B* represents the line on which the triangle is to be formed. Place the square so that 12 inches

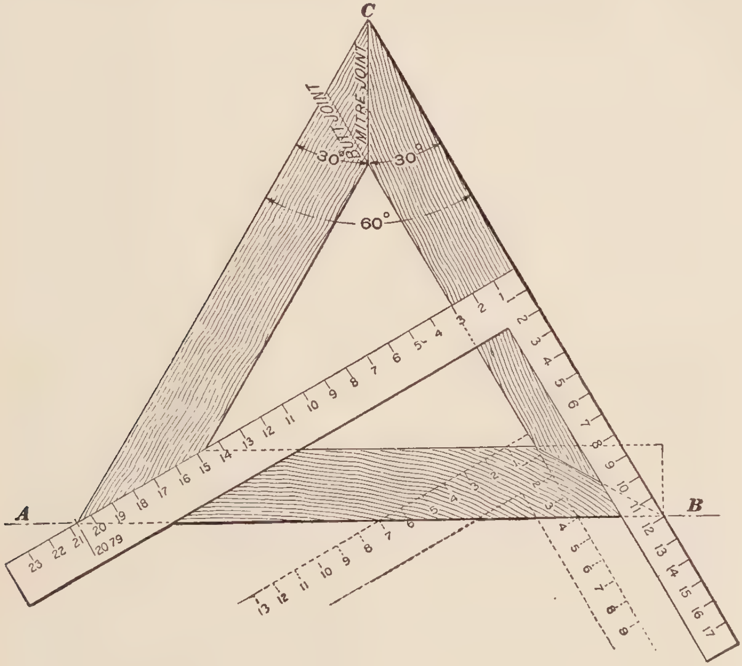


FIG. 49

on the tongue and 20·79 inches on the body are over the line *A B*; the tongue will then give the direction of one side of the triangle. By reversing the square so that the 12 inches is at *A* and the 20·79 inches is at *B*, the other side of the triangle may be drawn. The intersection of these two lines at *C* completes the triangle.

65. If a frame is to be constructed, the body of the square will give the direction to cut for a mitre joint. If a butt joint

is required, however, the cut will be along the tongue, using the same figures on the square. The mitre joint makes an angle of 30° with the sides, while the butt joint is parallel with the sides. The direction of these cuts can also be found by using 7 inches on the body and 4 inches on the tongue. While these figures are not absolutely correct, they are close enough for all practical purposes. They may be proved by using the proportion 20·79 : 12 = 7 : 4·04, which will show that 4 inches is ·04, or about $\frac{1}{32}$ inch too short.

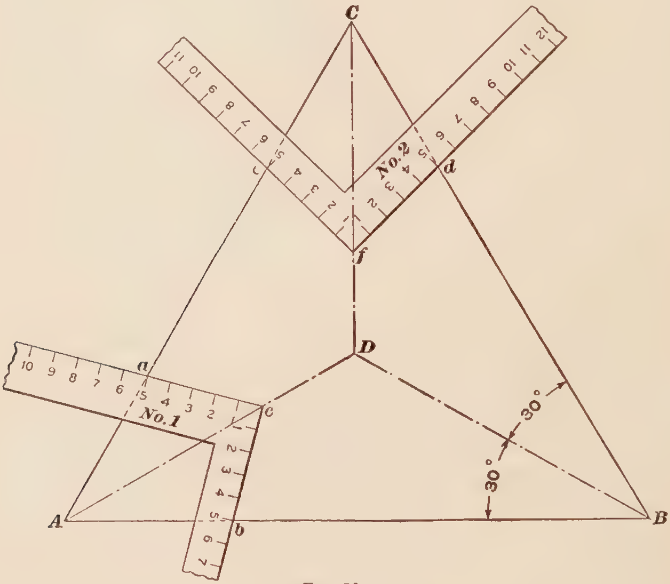


FIG. 50

66. Finding the Centre of a Triangle.—Fig. 50 shows one method of finding the centre of a triangle, also a method of bisecting any angle; this same method may be used to find the centre of any regular polygon. The triangle is represented by *A B C*. Make *A a* equal to *A b*, and place the square as shown at *No. 1*; that is, with equal divisions resting on the lines *A C* and *A B*, at *a* and *b*. Make a mark at the heel of the square, as at *e*, and from *A* through *e* draw a line of indefinite length. From the angle at *C*, set off *C c* and *C d* equal to each

other. Place the square, as shown, at *No. 2*, and make a mark at *f*. From *C*, through *f*, draw a line intersecting the line *a D*; then, *D* will be the centre of the triangle. To prove the work, the same operation may be repeated at angle *B*. Then, if the line *B D* intersects the other two lines at *D*, the operations at *A* and *C* have been performed correctly. The lines *A D*, *B D*, and *C D* bisect the angles *A*, *B*, and *C*, respectively. In the illustration, the 5-inch mark is used on both the body and the tongue of the square; any other figures may be used, however, provided they are at equal distances from the heel of the square.

67. Setting Out a Regular Quadrilateral Polygon or Square. By placing two squares as shown in Fig. 51, a regular square polygon is formed, the outer edges representing a square with 12-inch sides. Now, if a line *a b* is drawn diagonally from 12 inches to 12 inches, on measurement it will be found to be 16·97 inches long, but for most practical purposes, 17 inches will be found sufficiently exact. The constant, 17 inches, plays a very important part in roof framing. By assuming that the 12 divisions on a square represent feet instead of inches, the 17 will also represent feet. Now, assuming

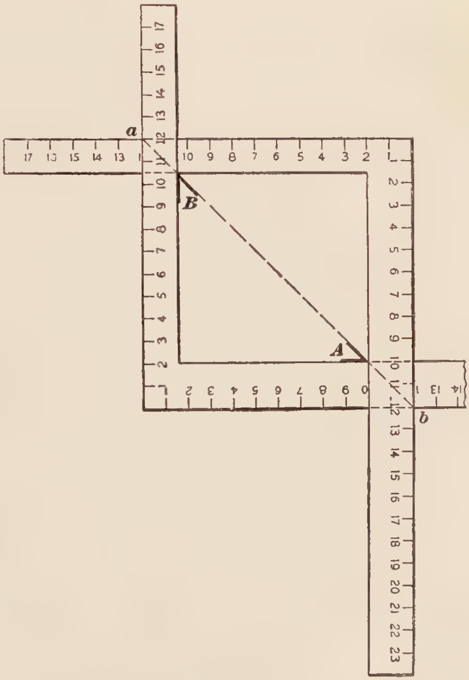


Fig. 51

that the *12* on the body represents the run of a rafter, and that the *12* on the tongue represents the rise, then the 17 will represent

the length of the rafter. This operation will also give the cuts of the rafter at the plates and ridge. Bevel A will give the correct angle of cut at the plate, and bevel B will give the correct cut at the ridge.

68. Setting Out a Regular Pentagon, or Five-Sided Polygon. In Fig. 52, $A\,B\,C\,D\,E$ represents the outside of a pentagon. To construct the pentagon, place the square, as shown, on the line $A\,b$, with 11 inches on the body and 8 inches on the tongue; mark along the tongue $A\,E$. Reverse the position of the square, as shown at $A\,B\,b$, and mark along the tongue $A\,B$. The two sides of the pentagon, or at least the direction of the two sides, will then be determined. To find the direction of the side $B\,C$, erect a line at right angles to the line $A\,E$ at *4*, or the centre of the line $A\,E$; then place the square as shown by the dotted lines. In the same manner, the direction of the other sides may be found, or the direction and lengths may be found by the use of compasses. In a similar manner, many other geometrical figures may be set out.

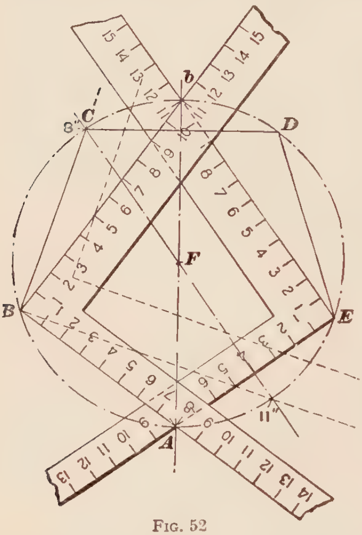


FIG. 52

69. Framing an Octagonal Post From a Square Timber.—A method of finding the points for an octagon on a square piece of timber is illustrated in Fig. 53, where $a\,b\,c\,d$ represents the end section of a piece of square timber. Lay the steel square on the timber in such a way that any 24 divisions on the square will be contained between two parallel sides, and then mark off 7 divisions from both sides. In the figure, the heel of the square is placed at one side and the 12-inch mark at the other, making 24 half-inch divisions. On one side, the 7 divisions will

therefore come at the $3\frac{1}{2}$-inch mark, and on the other at $12 - 3\frac{1}{2} = 8\frac{1}{2}$ inches, or the $8\frac{1}{2}$-inch mark. If the 6-inch mark is used

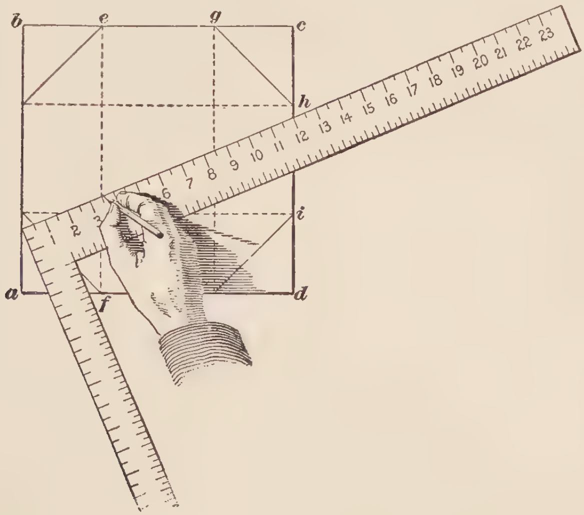


FIG. 53

for a diagonal width, each division will be equal to $\frac{1}{4}$ inch, and the marks will come at $1\frac{3}{4}$ and $4\frac{1}{4}$ inches, respectively. Fig. 54 shows the same principle applied to the side of the timber.

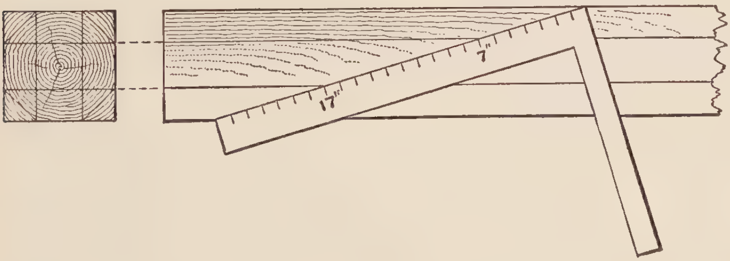


FIG. 54

The full length of the body of the square is used, thus making each division 1 inch, and the gauge marks come at 7 and 17 inches, respectively.

SETTING OUT STRUTS

70. The length of struts or braces may be obtained with a steel square without the aid of a brace scale. While the brace scale gives only a very few lengths, and these generally of equal runs and rises, the following methods will give the length of any strut with equal run and rise, also the lengths of struts with unequal runs and rises. The length of a strut is equal to the hypotenuse of a right triangle, as shown in Fig. 55.

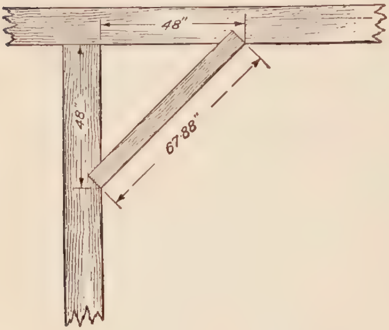


FIG. 55

71. Fig. 56 shows a method of obtaining the length of a strut by measuring the diagonal between the run and the rise. The length of a strut with an equal run and rise of 65 inches is required. As 65 is beyond the limits of the square, multiples of 65 or multiples of a part of 65 must be used. Take 60 and 5; the 5 is within the limits of the square, but the 60 may be brought within the limits by dividing by 4; thus, 60 ÷ 4 = 15. Then, to obtain the length, measure the diagonal, or *bridge measure*, between 15 inches on the tongue and 15 inches on the

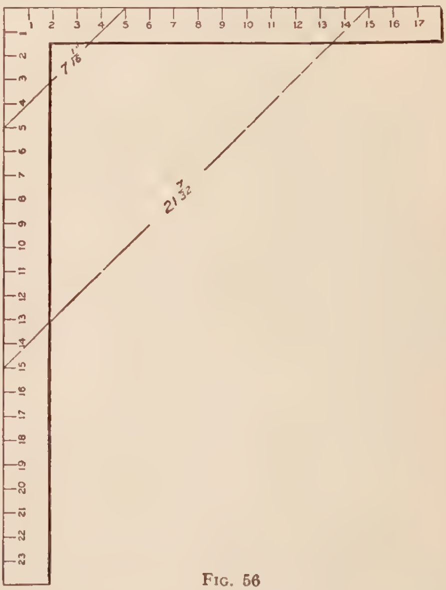


FIG. 56

body of the square. Multiply this distance by 4, because $4 \times 15 = 60$. Now, measure the diagonal between 5 inches on the tongue and 5 inches on the body of the square, and add this distance to the length of the diagonal of 15 and 15 multiplied by 4. The diagonal of 15 and 15 is found to be $21\frac{7}{32}$ inches, and that of 5 and 5 is $7\frac{1}{16}$ inches; $21\frac{7}{32} \times 4 = 84\frac{28}{32}$, and $84\frac{28}{32} + 7\frac{1}{16} = 91\frac{15}{16}$ inches, which is the length of the strut. The length of a strut with a run of 35 inches and a rise of 42 inches can be obtained in a similar manner, by taking 5 inches on the tongue and 6 inches on the body, and multiplying the diagonal, or bridge measure, thus found by 7, because $7 \times 5 = 35$ and $7 \times 6 = 42$.

SETTING OUT VARIOUS PARTS OF A STRUCTURE

STAIRS

72. Setting Out Stairs.—To obtain the figures on a square required to set out a string for a straight staircase, it is first necessary to know the rise and the run, or the distance between floors and the length of space available. In Fig. 57, the distance between floors is 10 feet 6 inches, or 126 inches, and the run is 12 feet 9 inches, or 153 inches. There will be 18 risers. To find the height of each riser, divide 126 inches by 18, which equals 7 inches. The width of the treads is found by dividing the run, 153 inches, by 17, which equals 9 inches. As the floor at the landing makes one of the steps, there is one tread less than there are risers. Then, by taking 7 inches on the body and 9 inches on the tongue, and marking along the body for the tread and along the tongue for the riser, the string may be marked out as shown in the illustration.

73. Setting Out Stair Strings.—In an open-stair string, the risers and strings are mitred. Yet, though they stand at an angle of 45° to each other, the mitre, owing to the pitch of the stair string, is not a square one, but changes with the pitch. In Fig. 58 (*a*) is shown how the cut on the string may be obtained by means of the square. The pitch board at (*b*) shows a tread

of 8 inches and a rise of 6 inches; the hypotenuse is therefore 10 inches Take the length of the tread, which in this case

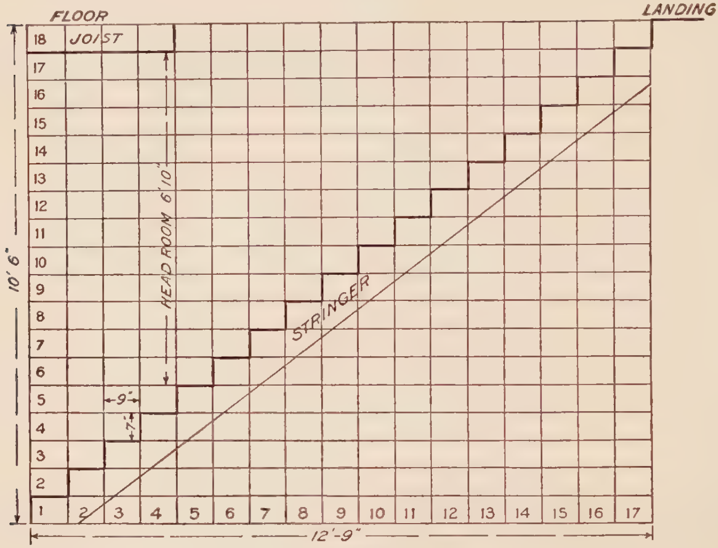


FIG. 57

is 8 inches, on the tongue of the square, and the length of the hypotenuse, which is 10 inches, on the body of the square, and

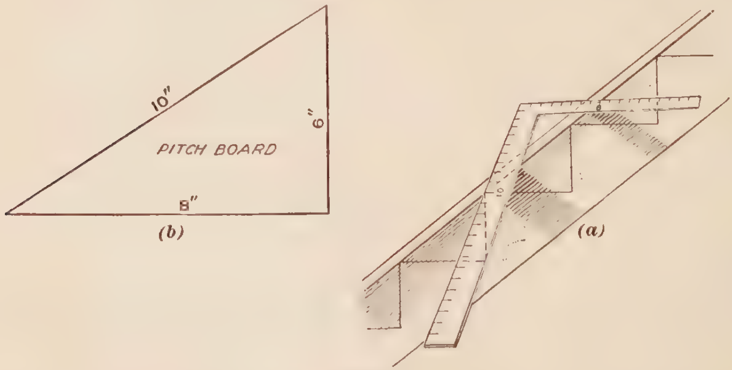


FIG. 58

apply to the string as shown at (*a*), marking along the body for the mitre cut. The cut on the riser will be a 45° angle.

ROOF FRAMING

74. The steel square may be used to solve many problems that would be very intricate without its aid; but its greatest usefulness is perhaps in roof framing, to which class of work it seems particularly adapted. It is only possible to give one or two examples of the use of the steel square in connection with roof framing, but from these examples an idea of the method of its application will be obtained.

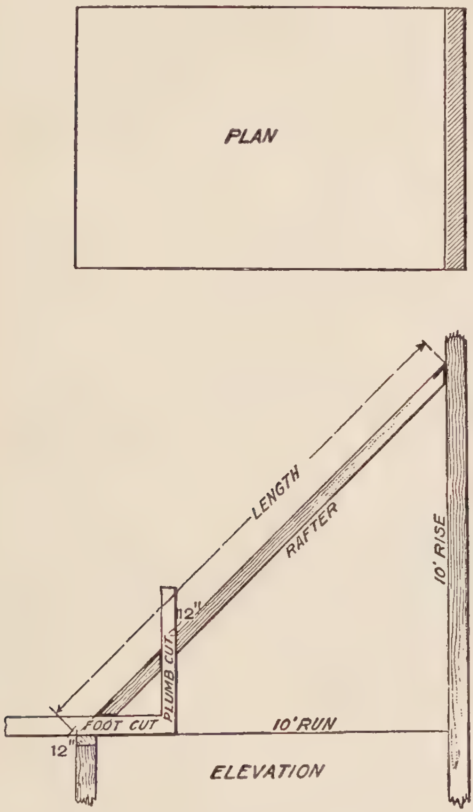


Fig. 59

75. Setting Out Common Rafters.—In Fig. 59 are shown a plan and elevation of a *shed*, or *lean-to*, *roof*, which is one-half of a saddle roof. This figure also illustrates a method of setting out a common rafter, both the run and the rise of the rafter being 10 feet. As placed in the illustration, the square shows a rise of 12 inches to a foot of run, which is the same as a $\frac{1}{2}$ pitch. The figures to be used on the square, therefore, are 12 inches on the body and 12 inches on the tongue for both the foot- and the plumb-cuts. The length of the rafter can be found by stepping along the rafter timber ten times, because in this case the run is 10 feet.

76. When a portion of a common rafter projects beyond the plate, it can be set out as shown in Fig. 60, which illustrates a section of a saddle roof having a run of 13 feet and a rise of 6 feet 6 inches. The squares placed at the foot and at the top of the rafter in (*a*) show the figures 12 on the body and 6 on the tongue as the ones to be used to obtain the foot- and the plumb-cuts. As the run is 13 feet, it will be necessary to step along the rafter thirteen times to obtain the length of the rafter. This roof is a ¼-pitch roof, the rise being one-quarter of the

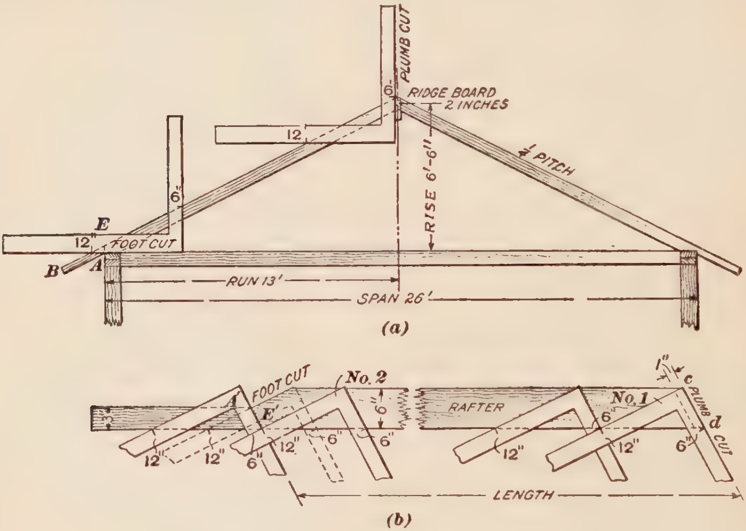


FIG. 60

span of the building. One foot, or 12 inches, is the standard measurement taken on the body of the square to represent the run. For the rise, the figure is determined by the number of inches the roof rises per foot of run. As shown in the figure, the lower end of the rafter projects the distance *A B* beyond the face line of the wall plate. This distance should therefore be added to the length of the rafter found by stepping thirteen times.

77. To set out the rafter, including the projecting portion, proceed as shown in Fig. 60 (*b*). Place square *No. 1* at one

end of the rafter timber, with the 12-inch mark on the body and the 6-inch mark on the tongue, even with the top edge of the timber, and then mark along the tongue, as shown at *c d*, for the plumb-cut. Step along the timber thirteen times to A', or to the 12-inch mark on square *No. 2*. Place the square once more, with the same figures, and from A' draw the line $A'E'$. Mark a point on this line at the required width of the projecting part of the rafter, as at E', 3 inches wide; then place the square at the mark E', as shown by the dotted square, and draw a line for the foot-cut. This mark is at right angles to the tongue of the other squares and the rafter has been raised the distance $A\ E$ above the plates, as shown in Fig. 60 (*a*). The rafter is not ready to put in place, however, until a portion of the top equal to one-half the thickness of the ridge board is cut off. If the ridge board is 2 inches thick, measure back 1 inch at right angles to the plumb-cut at the top of the rafter. This cut is shown in (*b*). In practice, instead of making two cuts of the top of the rafter, allowance is made for the ridge board and the necessary thickness removed in one cut.

78. To set out a common rafter when the run contains a fraction of a foot, resort is had to the method illustrated in Fig. 61, which shows in (*a*) the gable end of a building that is 21 feet 2 inches wide from plate to plate. For a building of this width, the rise and the run of the rafter are each 10 feet 7 inches; consequently, the roof is $\frac{1}{2}$ pitch, because one-half the span equals the rise. The figures to use on the square for the cuts are 12 inches on the body and 12 inches on the tongue. To set out the rafter proceed the same as in Fig. 60 (*b*). The distance *a b*, Fig. 61 (*b*), represents the length of the rafter for a 10-foot run. Place the square again from *a*, with 12 inches on the body and 12 inches on the tongue. From the heel of the square, measure 7 inches along the body to *c*. Slide the square backwards to *d*, and draw the line *d e*. The point *d* is determined by the intersection of a plumb-line drawn from *c* with a gauge line indicating the thickness of that portion of the rafter which projects beyond the plate. This operation shows that an addition to the length of the rafter is obtained that is

equal to the distance *d f*. If the run of the building were 10 feet, the foot-cut of the rafter would be at *f g* instead of *d e*. In a similar manner the whole of the timbers for the framing of a roof may be set out, and their foot and head cuts obtained,

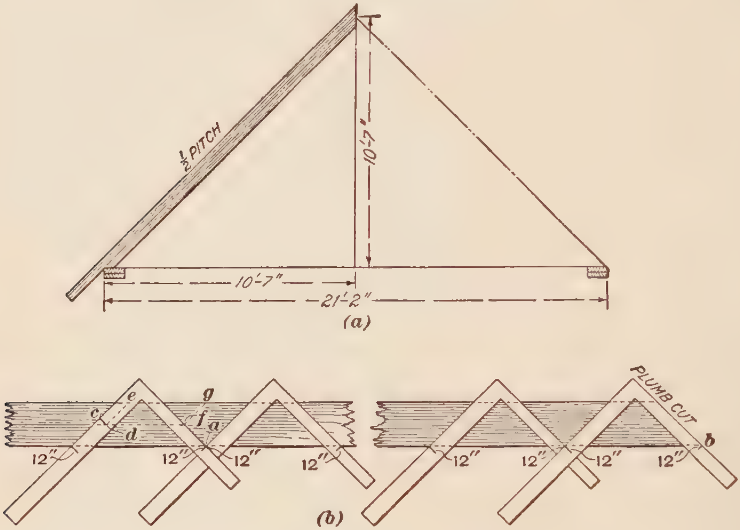


Fig. 61

and when the principles of the steel square have been thoroughly mastered, little difficulty will be experienced in applying it quickly to many uses for obtaining cuts in framing timbers which occur in everyday work.

ROOFING

PITCHED AND FLAT ROOFS

INTRODUCTION

ORIGIN OF ROOFING

1. Prehistoric Roofing.—The origin of roofing is to be found in the endeavour and determination of man to provide for his physical wants and comforts. In his primitive state he imitated birds and beasts in his attempts to obtain shelter, appropriating caves or building rough huts of twigs and branches, which he covered with leaves or the skins of animals. In the course of time the hut of wood or stone superseded these rude dwellings, and the roofs were often formed of thatching. The first real roof covering after the thatch was probably erected by the Assyrians. It consisted of square timbers placed close together, the upper surface of which was covered with thick layers of earth, beautified in many cases by flowers, etc.

2. Earliest Use of Various Materials.—The next step in roof covering was taken when the earlier Egyptians and peoples who followed them constructed roofs of flat slabs of stone, which were supported on stone lintels or beams resting on columns. These in turn were succeeded by tiles laid on boards or vaulted stone roofs. Tiles were used in China as roofing as early as the year 2000 B.C. They were mostly flat tiles turned up at their edges, with a row of inverted, semi-cylindrical tiles placed over the joints. Metal roofs are of much more recent origin. Lead was

the first to be introduced; copper, zinc, tin, and galvanized iron followed. Lead was used largely in mediæval times. Wooden shingles and slate were known at an early period, but the latter material was then used in the form of slabs, which were of great weight.

ROOF PITCHES

3. Comparative Pitches.—In planning a roof, one of the first considerations should be its pitch or slope, which depends to a great extent on the material to be adopted and the climate of the locality in which the building is situated. Another important

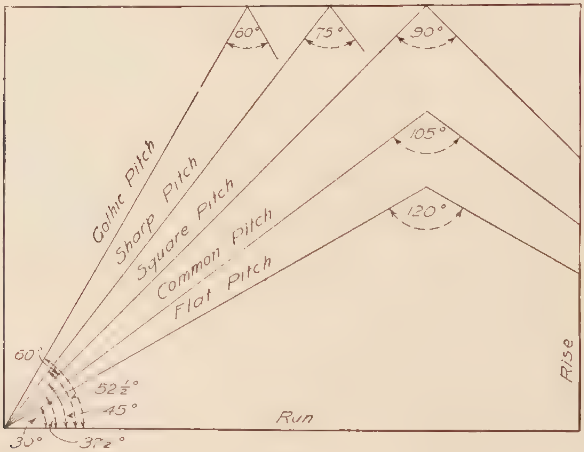


FIG. 1

consideration is the devices of construction to aid the free flow of water from the whole external surface of the roof.

In Fig. 1 is shown a diagram giving the comparative pitches for roofs as generally adopted by architects, and, although these pitches are subject to modification, it will generally be found advisable to keep near to them, as tile and slate merchants stock ridge, hip, and valley tiles and slates to work with these angles.

In Table I is given a list of roofing materials and the minimum pitch advisable for each when laid on roofs. In the case of gutters, the metal used may be laid to a slope of 1½ inches in

10 feet. Although there are no invariable rules governing the pitch of roofs, it is the custom to construct with a slope suited to the material, and to base the choice of the material on the relative importance of the building and on the local conditions of supply and transport.

4. **Pitch Adapted to Climate.**—In cold climates, where the air holds moisture, and rain and snow are driven by high winds, the pitch must be steep, to prevent the loosening of shingles,

TABLE I

MINIMUM SLOPE OF ROOFING MATERIALS

Roofing Material	Minimum Slope
Lead	2 inches in 10 feet
Zinc	2 inches in 10 feet
Copper	2 inches in 10 feet
Tin	2 inches in 10 feet
Asphalt	2 inches in 10 feet
Composition roofing . .	2 inches in 10 feet
Corrugated iron . . .	12° with the horizontal
Sheet iron	12° with the horizontal
Slates	26° with the horizontal
Pan tiles	33° with the horizontal
Plain tiles	45° with the horizontal
Thatch	45° with the horizontal
Shingles	45° with the horizontal

slates, or tiles by the wind, and to cause snow and moisture to be quickly shed from the roof.

In hot countries, the lack of rain makes it unnecessary to give the roof more pitch than enough to shed the water; but the roof must be well constructed and water-tight, for when rain falls in hot regions it does so in large volumes. Rapid evaporation is a great help in preserving the roof, for when the rain ceases the roof is soon dried, and the conditions tending toward corrosion or decay of the materials are removed.

5. Precautions at Angles and Intersections.—The roof should be carefully prepared for the covering, and all pockets, where ice, snow, or water can accumulate, must be avoided in the construction. On steep roofs, the backs of chimneys or other vertical walls cutting the roof plane must be fitted with gutters having a good fall. All sharp angles made by corners or flashings against walls should be avoided, and a fillet should be used to allow the flashing to take an easy bend. In slate and tile roofs, this precaution will assist the passage of water and snow and prevent its accumulation. On metal roofs, sand, dust, or other refuse blown thereon will not lodge very readily. Where such accumulations do lodge on the roof, they keep it damp, rotting and corroding the most vulnerable parts.

6. Roof Boarding.—The roof boarding should run one way, so that the shrinkage may be uniform and not pull and tear the joints of the roofing material. With metal roofs, it is best to have the boards laid from the eaves to the ridge, as this, in case the boards warp, brings the ridges thus raised in the roof in line with the current of water. This is not always practicable, but in any case it is possible to lay the boards diagonally. The laying of boarding diagonally is often adopted on pitched roofs of light construction, as boarding laid in this way stiffens the roof. The nails driven from the surface of the roof should be punched in at least ¼ inch below the top surface of the boards, to prevent corrosion and the heads from wearing through the covering.

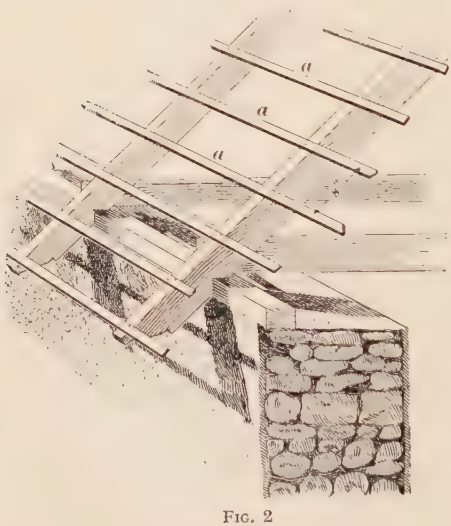


Fig. 2

COVERINGS FOR PITCHED ROOFS

THATCH ROOFING

7. Use of Thatching.—A roof covering consisting of bundles of straw or reeds is called **thatch**. This style of covering is admirable for securing warmth in winter and coolness in summer, but, being subject to injury from birds and great risk from fire, it is practically never used in urban districts. In fact, in a great number of municipalities the local building by-laws prohibit the use of thatching. In rural districts, however, dwelling houses of good class as well as cottages are not infrequently constructed with thatched roofs, and the roofs of farm buildings are often of this kind.

8. Methods of Thatching.—The roof is prepared to receive the thatching by nailing to the rafters laths at 8-inch centres, as shown at *a*, *a*, Fig. 2, on which the straw is laid. Like slating or tiling, the thatching is commenced at the eaves. Bundles, about 3 or 4 inches in thickness, are laid on and secured to the laths, a thatcher's needle and rope yarn being used. The yarn is tied round the laths, as shown at *a*, *a*, Fig. 3, or hung with thatching hooks, which are tied to the head of each bundle and hooked over the laths. Starting at the end

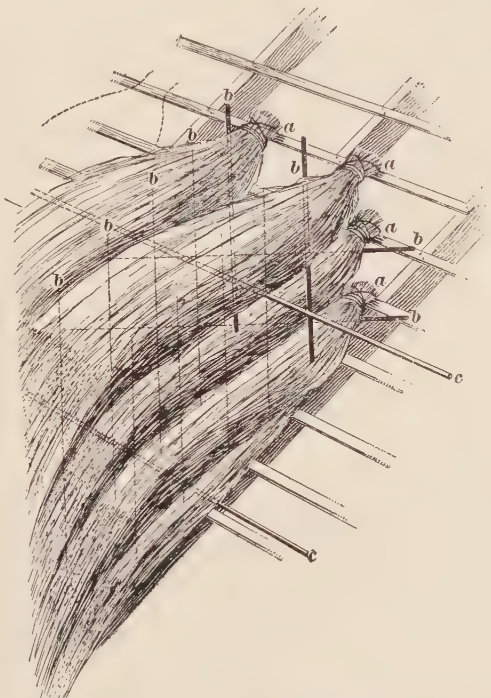


Fig. 3

wall, or at the gables, full-width bundles are laid until a row reaches the ridge, the thickness of the thatch when completed being from 12 to 15 inches.

After two or three rows have been put on, they are interlaced with *withes*, or *reeds*, as shown at *b*, the ends of the withes being bound together and nailed to the rafters. The withes may also be tied to the laths with the yarn. After 8 or 10 feet has been laid the rods *c*, *c* are run through the thatch. These rods are spaced about 2 feet apart, and are secured by looping a withe over them and nailing the ends to the rafter.

9. Undesirable Features.—Gable walls carried higher than a thatched roof are undesirable, as they entail great difficulty in securing protection from the weather at the point where the thatching abuts them. If the nature of the building does not permit of the eaves being carried all round the house, the gable walls should end under the rake of the roof, and the thatch be extended over them and finished in a similar manner to the eaves. The ridge may be formed of thin bundles of straw, laid with the middle on the ridge and afterwards withed down to the roof, as in Fig. 4 (*a*); or sometimes the straw ends of the upper layer are turned up and withed together and surmounted by a terra-cotta ridge cresting set in cement, as shown in Fig. 4 (*b*). This method,

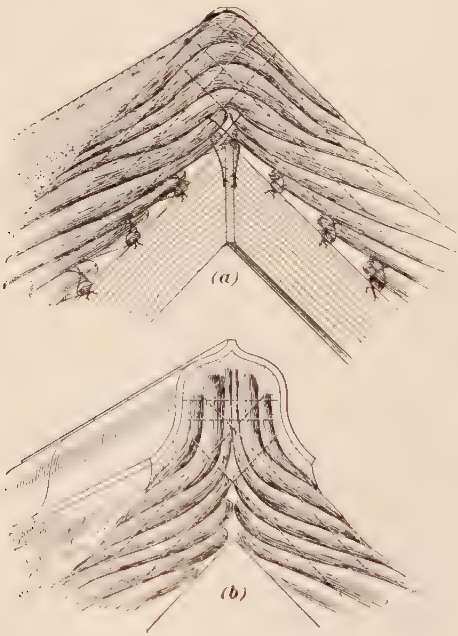


FIG. 4

however, detracts from the picturesqueness of the roof and is quite out of character with thatched work.

10. Conveyance of Rain-Water.—The eaves may be raked out until the edge is very fine, thus forming a round, easy shed for the water, as shown in Fig. 5 (*a*), or cut off on the under side, as shown in Fig. 5 (*b*). As each course is laid, the lap ends should be raked out, to maintain as even and continuous a surface in the finish as possible.

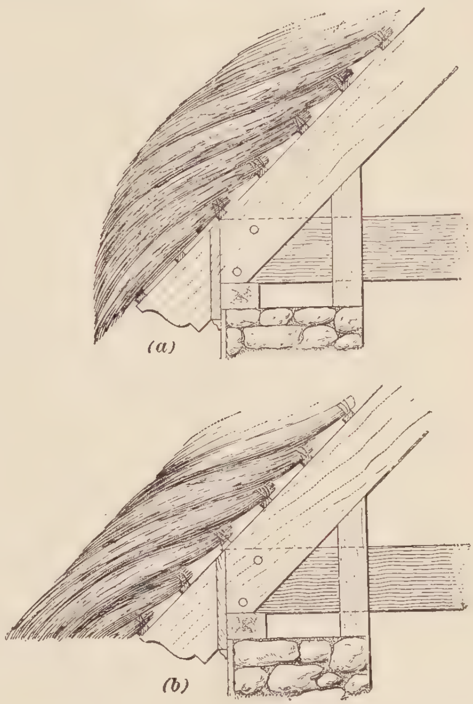


Fig. 5

It is somewhat difficult to provide a suitable gutter to convey rain-water from the roof. In many cases water from the eaves is allowed to drip on to the ground beneath, where a trench has been dug directly under the drip line, drained by a 3- or 4-inch land drain pipe with open joints. The pipe is laid to proper fall and conveys the water to any desired well or pond. The trench is then filled with broken brick rubble or clean coarse gravel, and covered with mould as desired. If gutters are used, they are generally either V-shaped troughs of wood or half-round iron gutters of the ordinary type.

11. Implements and Materials for Thatching.—The thatcher requires the following: A common stable fork, to toss the straw together before it is made into bundles; a thatcher's fork, to

carry the straw up to the roof ; a thatcher's rake, to comb the straw straight and smooth ; a knife, to point the withes ; a half glove of leather, to protect the hand when drawing or pushing in the smaller withes ; a long, flat needle ; and a pair of leather gaiters, to come above the knees, for protection when kneeling on the rafters. The materials required are good straw of any kind, or straw reeds, wheat straw being the best ; also rope, nails, withes, and rods. A machine is now on the market which is used for sewing up the bundles with either twine or wire, by which they are secured to the roof timbers below.

SLATES AND SLATING

12. Qualities of Slates.—Good slates for roofing purposes should possess both toughness and hardness, and a very fine but easily distinguished grain. They should be tough enough to be easily punched for nailing, and should cut to standard sizes without splintering or becoming friable at the edges. They should also be practically non-absorbent, for the action of frost on a slate containing moisture will cause the edges to crumble and will also tend to enlarge the nail holes, thus causing the slate to loosen from the roof.

The grain should run lengthwise of the slate. Veins or ribbons are objectionable markings, especially when parallel with the grain. Crystals of pyrites are sometimes found in slates. The yellow variety is found to be practically unobjectionable. Slates containing white pyrites, however, should always be rejected. The colour of slates varies considerably, and is in no way indicative of the quality of the material. Blue, blue-black, purple, grey, green, and red are the most common tints, although cream colour is occasionally found.

13. Tests of Quality.—Slates vary in quality with the characteristics of the rock, as do also the straightness, smoothness of surface, and uniformity of thickness of the quarried product. Tests to determine the quality of slates are sometimes made, but cannot be relied on, although they are of value in some instances where certain characteristics are to be determined.

The *porosity* and amount of absorption may be obtained by weighing a dry slate, as delivered from the quarry, and reweighing it after soaking it in water from 24 to 36 hours; the difference in weight shows the amount of water absorbed. If this is more than $\frac{1}{200}$ of the weight of the slate itself when dry the sample is of poor quality. A slate may also be permitted to stand on edge in a shallow dish of water, the height to which the water rises in the pores being noted. If, after standing for 12 hours, the water has not risen more than $\frac{1}{8}$ inch, the slate may be accepted without doubt, for it is practically nonabsorbent.

Slates submitted to the action of dilute sulphuric acid will, if of a proper degree of hardness, remain unchanged for several weeks, but, if of soft quality, will decompose and crumble in a few days. Powdered slate, submitted to the action of muriatic acid, will effervesce strongly when it contains carbonate of lime, and should not then be used for roofing purposes. Powdered slate submitted to a high temperature will give off a yellow sublimate of sulphur when it contains pyrites, and should not be used, as it is not of a durable quality.

14. Although the foregoing tests tend to show some of the characteristics of different qualities of slates, they are not entirely reliable in determining the value of the slates as a roof covering, for some of the hardest slates will undergo decomposition on the roof, even after passing all the preliminary tests. A good slate should present a bright, silk-like lustre, and emit a clear, metallic ring when struck with the knuckles, showing that it is hard; if it is soft, it will have a dull, lead-like surface and give out a muffled sound. When cut, the edges should show a fibrous-like texture, free from splinters, and the material should not show signs of being either brittle or crumbly. No better test of wearing or weathering qualities can be applied than the simple and effective one of examining roofs where slates from the same quarry have been fixed for several years.

15. Varieties of Slates.—The number of quarries from which roofing slates can be obtained is so great that a few only can here be mentioned. The chief supply of slates in the British

Isles is obtained from North Wales, where Bangor and Portmadoc slates are quarried in very large quantities. There are many quarries in each of those localities, but generally speaking the term Bangor refers to all slates quarried from the Bangor district or range, which are purple, blue, or red in colour, while Portmadoc is the name of a port whence slates quarried in the neighbouring district are shipped. Portmadoc slates are of a blue colour. Dark-blue Carnarvon slates of excellent quality are obtained from quarries at Bettws-y-Coed, and olive-green slates can be procured from South Wales. For durability and colour perfection Westmoreland green slates are generally considered the best on the market. These are much thicker than Welsh slates and are supplied in random sizes. Slates of a somewhat similar character are obtained from Ireland. Cornish slates, which are of a grey-blue colour, are sound and reliable. Scotch slates are used locally to a considerable extent. These often contain iron pyrites, but as this is usually the yellow variety it does not interfere with the weathering qualities of the slates. Many varieties of imported slates from America, France, Germany, and other countries can be obtained, but great care should be taken when selecting them, as their quality and weathering properties often leave much to be desired.

16. Sizes of Slates.—With the exception of Westmoreland slates and other similar varieties, slates may be obtained in the

TABLE II

SQUARES COVERED BY SLATING

Name	Size Inches	Gauge Inches	Squares Covered by 1 Mil
Doubles	12 × 8	$4\frac{1}{2}$	2·9
Ladies	14 × 12	$5\frac{1}{2}$	5·3
Ladies (large) . .	16 × 8	$6\frac{1}{2}$	4·2
Viscountess . .	18 × 10	$7\frac{1}{2}$	6·0
Countess . . .	20 × 10	$8\frac{1}{2}$	6·8
Marchioness . .	22 × 12	$9\frac{1}{2}$	9·1
Duchess	24 × 12	$10\frac{1}{2}$	10·0

various stock sizes and are generally sold by number, not by weight, that is, by the *mil*, or 1,200 slates for every thousand. The sizes in general use, together with the gauge allowing for a 3-inch lap and the number of squares, 100 square feet, of roof surface that a mil of 1,200 slates will cover, are given in Table II. An additional allowance must be made for waste due to cutting, which will vary considerably in accordance with the form of the roof. In some districts the sizes of slates of the same names as those given in Table II may vary slightly, so that if extreme accuracy is necessary, the dimensions should be quoted, when ordering. The gauge values given in Table II are calculated for slates nailed near the centre.

17. Terms Used in Slating.—The terms applied to the different portions of a slated roof are: The **gauge**, which is the distance from nail hole to nail hole, as shown at *a*, Fig. 6; the **margin**, that portion of the slate exposed to the weather when laid, as shown at *b*, this being always equal to the gauge; the **lap**, which, in the case of head-nailed slates, is the distance each slate overlaps the nail hole of the second one below it, as shown at *c*; the **head**, or upper end of each slate, as at *d*; the **tail**, or lower end of each slate, as at *e*; the **bed**, or under surface of each slate when laid; and the **back**, which is the upper surface when laid. In slates which are nailed at the centre, the lap is the distance by which the tail of one slate overlaps the head of the second one beneath it. The gauge is in all cases the basis for the setting out of the slating.

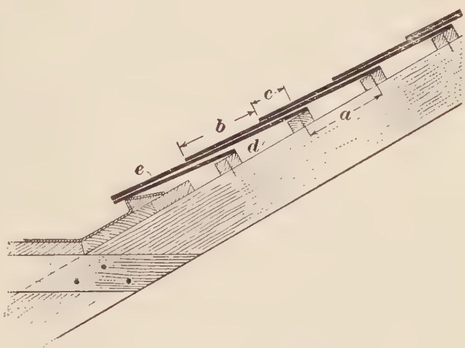


Fig. 6

Rendering consists in covering the under side of the slate with hair mortar. This is an operation often adopted when the slates are laid on battens, and it is sometimes employed when

the roof is boarded, by laying the slates on the mortar, which has first been applied directly to the boards. Rendering prevents the wind from blowing rain or snow through the crevices when felt is not used over the boards. It is not so effective when slates are laid on battens, as they are likely to settle and crack the rendering. The great objection to rendering is that it is liable to shrink slightly and leave a joint between it and the slate, through which moisture will be drawn by capillary attraction. This moisture, when reaching the timber or boarding, is liable to set up dry rot.

Shouldering is the application to the head of each slate, to a depth of 2 inches, of a thin bed of hair mortar or slater's cement. Shouldering is resorted to only in very exposed situations.

Torching is the pointing of the joints between the heads and tails of the slates from the under side with hair mortar or slater's cement, and is done after the slates are laid; it is of little value, as it soon falls out, leaving the joints open. Both torching and shouldering are resorted to only when slates are laid on battens, to prevent wind, wet, and dust from blowing through.

18. Methods of Nailing.—There are two methods of nailing slates: *Head-nailing* and *centre-nailing*. In **head-nailing** the nail holes are punched about 1 inch from the top, as at *a*, Fig. 7, and the tails of the next two courses, as *b* and *c*, lap over the nail holes. Should the first-covering slate *b* be broken, the nails are still protected from the weather by the lap of the second-covering slate *c*. The objection to this method is the leverage exerted by the wind. In the

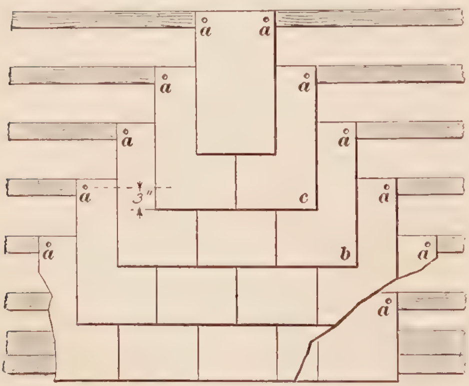


FIG. 7

case of large slates, the wind, if it gets under the slates, acts with such a leverage as to threaten the security of the covering. Head-nailing was at one time almost universally adopted, but is now in less general favour.

As regards **centre-nailing**, holes are punched at a distance from the tail of the slate equal to a little more than the gauge plus the lap, as at *a*, Fig. 8. Although by this method there is only the protection afforded by one slate over each nail hole, the greater security of fixing is considered to be a more than counterbalancing advantage.

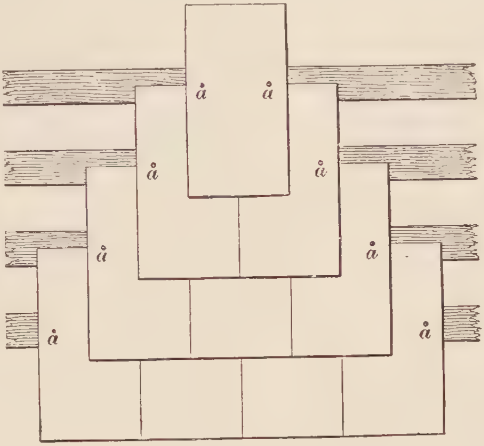


Fig. 8

19. Lap and Gauge of Slates.—The lap of slates is usually not less than 3 inches, except in the case of small slates employed on roofs of steep pitch, where a lap of $2\frac{1}{2}$ inches is sometimes adopted, but the lap of random-sized slates should not in any case be less than 3 inches. The size and lap of the slates being given, the gauge must be ascertained by calculation. In the case of head-nailed slates, the gauge is equal to half the remainder obtained by subtracting the lap from the distance of the line of the nail holes from the bottom of the slate. Thus, the gauge of $16'' \times 8''$ slates nailed at the head and laid with a 3-inch lap, the distance of the nail holes from the top of the slate being 1 inch, is

$$\frac{(16-1)-3}{2} = 6 \text{ inches}$$

For centre-nailed slates, the calculation is the same, except that in place of the distance from the nail holes to the bottom of the slate, the full length of the slate is taken.

The gauge of 20″ × 10″ slates nailed at the centre and laid with a 3-inch lap is

$$\frac{20 - 3}{2} = 8\tfrac{1}{2} \text{ inches}$$

20. Cut Slates.—The tail-ends of slates are sometimes cut on the corners so as to give, when laid, a semi-octagonal or triangular margin, and when so treated are termed **cut slates.** This method is sometimes adopted in the case of a band of slates of a colour different from the rest of the roof, provided to relieve the otherwise even colouring.

Cut slates also tend to shed the water more rapidly than square-end slates, as their form acts as a guide, carrying the water to a point it readily leaves, thereby clearing the roof quickly; while, with square slates, the water lodges in the joints, accumulates on the lower edge, and drips off so slowly that the joints are wet when the rest of the roof is dry. In a hard winter, the alternate freezing and thawing are likely to loosen the slates and cause the edges to crumble. A roof covered with cut slates is, however, not so strong as one covered with square slates, on account of the material which is cut away.

21. Sorting and Piling Slates.—Sorting and piling slates preparatory to laying is a most important detail of the slater's work. The slates should be piled with their edges up, the pile in no case being more than 3 feet 6 inches in height; the ends of the tiers may be held up by laying a pile of slates on the flat, while the top of the pile should be covered with slates laid flat to keep out moisture. The slates should be sorted or selected by grades of thickness, the thinner being piled first and the thicker next. Thick slates should be laid on the lower part of the roof, and the thinner at the top.

22. Random-Sized Slates.—Where Westmoreland or other similar random-sized slates are used, they are sorted in respect of both thickness and size, and are laid from eaves to ridge in courses diminishing in size. Slates of this kind are particularly suited for covering conical and other forms of pointed roofs, where, if standard-sized slates were used, it would be necessary to break

joints, an undesirable procedure which can be avoided when the slates are of different widths.

23. Holing Slates.—In holing slates for the nails, it is found that machine-punched slates are preferable to hand-punched. In Fig. 9 (*a*) is shown a section through a machine-punched slate; the hole is clean cut and gives the very best result; while in Fig. 9 (*b*) is shown a hand-punched slate whose edge is ragged and flaked, the slate consequently being weakened. In Fig. 9 (*c*) is shown another machine-punched slate, but with the nails driven too tightly. The result is as indicated. The slate has sprung to its natural position, pulling the head of the nail through, as shown, thus rendering it of little value for holding the slate. In Fig. 9 (*d*) is shown a machine-punched slate with the nail insufficiently driven; the nail head may then be forced through the upper slate by pressure from above.

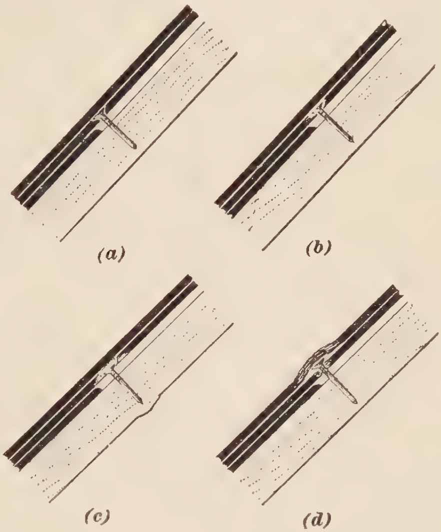


FIG. 9

The slates in the illustration are shown of an exaggerated thickness, and it will be observed that they are quite parallel, which they would not be when laid in position, the tiling fillet at the eaves lifting the tails of the slates in the eaves course. In the other courses the tails will rest on the slates beneath and the heads on the roof boarding.

24. Trimming Centre-Nailed Slates.—When the slates are centre-nailed, the slater usually trims the top portion about $\frac{3}{8}$ inch on the right-hand side, as shown at *a* in Fig. 10. This gives him a little freedom to move the slate either way, so that the tails of the slates may keep a perfectly true line when laid.

25. Methods of Slating.—Slates may be laid in any of the following alternative manners: (*a*) On wooden battens; (*b*) on boarding; (*c*) on boarding covered with felt; (*d*) on boarding and felt with battens laid on top of the felt; and (*e*) on boarding and felt with two rows of battens, one laid transversely on the other, and the lower series running parallel to the rafters, up the slope of the roof.

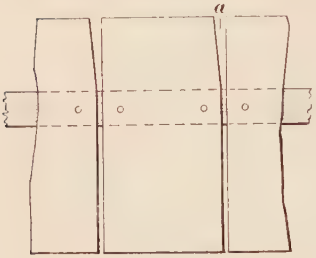


Fig. 10

26. Laying Slates on Battens.—In the method of laying slates on battens, wooden battens from 2 to $2\frac{1}{2}$ inches by $\frac{3}{4}$ to 1 inch are laid across the rafters and fixed apart at a distance equal to the gauge of the slates. These battens are securely nailed to the rafters and the slates are nailed to the battens. This method is adopted only where the chief consideration is cheapness, as there is no protection under the slates to prevent snow, rain, and dust from blowing in the building by passing between the slates.

27. Laying Slates on Boarding.—The method of laying slates on boarding is an improvement on that just described. The boarding often consists of plain butt-jointed boards, but sometimes of grooved-and-tongued boarding about 6 inches wide by 1 inch or $1\frac{1}{4}$ inches thick. The objection to wider boards is that they are likely to shrink, curl on the edges, and lift some of the slates, thereby giving the roof a rough, uneven appearance. If wide boards are used, however, they must be well nailed at both edges. More care in this respect is needed when the boarding is applied to curved roofs or round towers, in which cases the boarding must be perfectly solid and smooth. When it is not solid, the driving of a nail is almost sure to loosen the slate that has previously been nailed, and a uniformly tight job is impossible.

28. Laying Slates on Felt-Covered Boarding.—The method of laying slates on boarding covered with felt is exactly similar to that in which felt is not used, except that before the slates are laid the boarding is covered with a layer of heavy, specially

prepared, tarred roofing felt. This felt serves as an extra protection in keeping out wet and wind. It is generally laid parallel to the eaves, but if the roof is of very steep pitch it may be laid in the direction of the slope of the roof. In either case, the different widths should be lapped over one another about $1\frac{1}{2}$ or 2 inches and be securely fastened to the boarding with nails having large flat heads.

29. Best Methods of Laying Slates.—In laying slates on boarding and felt with battens laid on top of the felt, the process adopted is similar to that employed when slates are laid on battens. The battens are, however, securely nailed to the felt-covered boarding instead of to the rafters direct. This is a good method, but a better one, though more expensive, is that in which the slates are laid on boarding and felt with two rows of battens, one transversely on the other. This method is adopted only in the very best class of work, and its advantage is that if a slate is broken and water penetrates underneath it, the water will run away instead of being retained in the top of the battens, as would be the case if only a single series of battens were used.

30. Half Slating.—A method of slating known as **half slating**, which is illustrated in Fig. 11, is sometimes used, but generally only on cheap buildings where economy is the first consideration. If laid on battens, half slating should be used only when a perfectly weather-tight roof is not necessary; but if laid on boards covered with felt, it gives a good, serviceable, low-priced roof. The lower courses should always be laid double. The courses above this have a space *a* between the edges of the slates in each row equal to one-half the

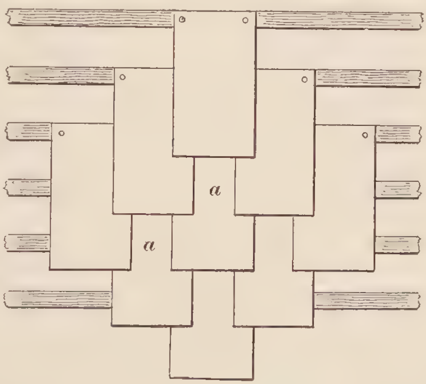


Fig. 11

width of each slate. The whole surface is thus laid up to the ridge, the last course and ridge roll being finished as in ordinary slating. Half slating on battens is especially advantageous for roofs where extra ventilation is desired, both to admit fresh air and to allow steam, smoke, gases, etc., to escape.

31. Tools Used by Slater.—Besides the mallets, saws, chisels, etc., used by a stonemason, the slater has a few special tools employed only in the work of slating a roof. These are shown in Fig. 12 (*a*), (*b*), and (*c*), in which (*a*) is the **slater's axe,** or **zax** as it is sometimes called, used for trimming the edges of slates. A slate is cut by resting it on what is called a **dog,** which is simply an iron straightedge with a spike at each end by means

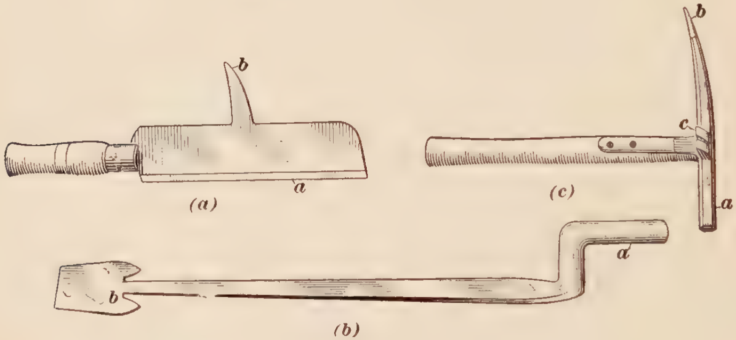


Fig. 12

of which it can be fastened to a board or wooden log. The axe is then taken in hand, and by means of the cutting edge *a* the slate is trimmed off along the iron straightedge at any point desired. The pick *b* at the back of the axe is used for holing slates for nails, when this is done by hand.

In (*b*) is shown the **ripper,** a thin steel blade about 2 feet long with a projecting handle *a*. It is used by a slater, when repairing a roof, for removing broken slates. The shaped and flattened end *b* is slipped up under the slate and by a sharp movement of the tool the nails are cut in two, thus allowing the broken slate to be drawn out preparatory to inserting a new one. The **slater's hammer** is shown in (*c*). It consists of a hammer head *a*

used for driving the nails when fixing slates, a pointed end *b* for holing a slate, when this has to be done on the roof, and a claw *c* at the side to pull out broken or defective nails.

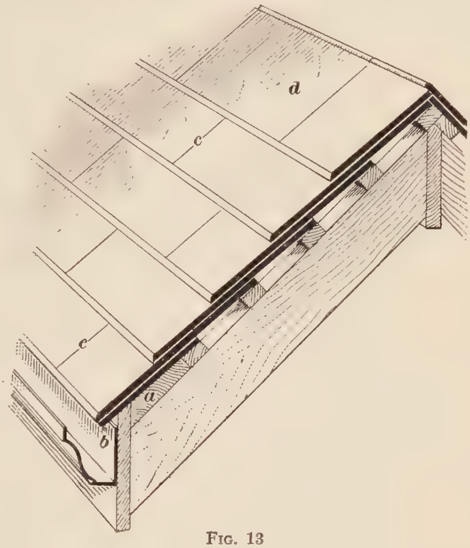


FIG. 13

32. Placing the Slates.—In commencing to slate a roof, the first course is laid at the eaves, and in all good work is laid double, the lower or *undereaves* course having a length equal to the gauge plus the lap, as seen at *a*, Fig. 13, and should project over the eaves or gutter edge from $1\frac{1}{2}$ to 2 inches, as at *b*. All the courses must be laid so as to break joints, as shown at *c*. The last course, as at *d*, is known as a *finisher*, and is put on to receive the ridge roll.

When the edges of a slate are trimmed, the face, which is placed upon the iron straightedge, remains true and regular; while the edge of the slate on the other face is rough and uneven, and forms a ragged splay. In laying the slates, the smooth side of the slate is placed face downwards, so as to make a close fit at the tail with the slate underneath. This applies to all slates except those in the undereaves course, which, as shown in Fig. 14, are laid with the smooth face uppermost.

33. Wooden Tilting Fillets.—Wooden tilting fillets should always be used when the roof is covered with boards, and are always necessary when slating is fixed to battens, unless the fascia is kept up above the battens. The fillet is shaped as shown at *a*, Fig. 14, and extends the full length of the gutter. The lead or other metal used to form the gutter is generally carried over the top of the tilting fillet and a few inches up

underneath the slates. The method of laying slates or shingles flat on sheet-metal gutters, valleys, flanks, or other flashings should never be followed. Water will work up between them by capillary attraction, which it cannot do when a tilting fillet is used.

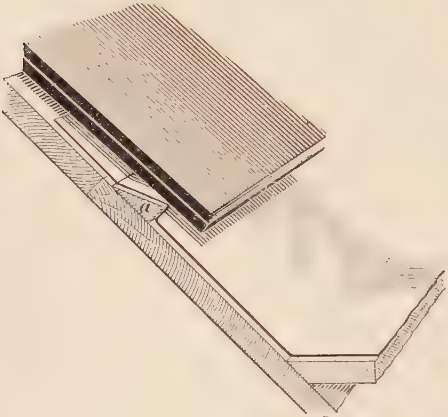


Fig. 14

34. Nails for Slating. The nails used for slating have large flat heads, so that they may secure a good hold on the surface of the slate, and are from $1\frac{1}{4}$ to 2 inches long. The proper length of a nail is twice the thickness of the slate, plus the thickness of battens or boarding; this length will give the full amount of hold that can be secured. The nails generally used in the best work are of copper, $1\frac{1}{4}$ inches or, in exposed situations, $1\frac{1}{2}$ inches long. Copper nails are non-corrosive, but on account of their cost are not very greatly employed. Composition nails, composed of an alloy of zinc, tin, and copper, are much used, and are preferred by many architects to copper nails, as they are tougher and less likely to bend. Zinc nails are also sometimes adopted, but they are soft and require to be used with greater care than composition nails.

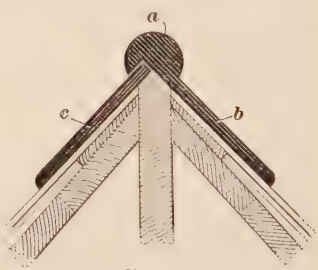


Fig. 15

35. Ridges and Hips on Slated Roofs.—Ridges and hips on slated roofs may be finished either with a slate roll and wings, or with a wooden roll covered with lead, zinc, or copper; or tile ridges and hips, of the kind described in *Terra-Cotta, Faience, and Tiling*, may be used. A slate ridge is illustrated in Fig. 15. It consists of a

roll *a* with a wing *b* cut out of the same piece of slate, and a loose wing *c*, which is usually secured to the ridge by means of copper screws, the whole ridge being bedded in cement. A rule for proportioning the wings to the roll is as follows: With a 2-inch roll, a 5½-inch wing is to be used; with a 2½-inch roll a 6-inch wing, and with a 3-inch roll a 7-inch wing, are to be used.

36. Wooden Rolls for Ridges and Hips.—Wooden rolls for ridges and hips are about 2 inches in diameter and are usually covered with lead, which is laid in lengths of about 7 feet with lapped joints, and is of sufficient width to extend about 6 inches down each side of the roof, as shown at *a*, Fig. 16. The lead is sometimes not secured in any manner, but it is desirable to fix it by means of lead tacks *b*, which are short strips of sheet lead, about 2 inches to 2½ inches wide, spaced from 2 to 3 feet apart. These tacks pass underneath the wooden roll, being laid before the roll is fixed, and are turned up at the ends to clip over the bottom edges of the lead in order to prevent it from being lifted by the wind.

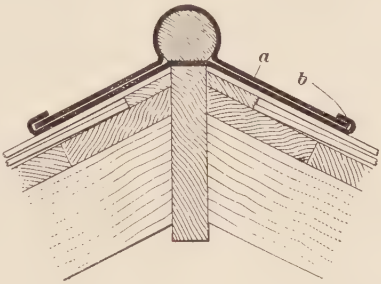


Fig. 16

Hips may be treated in a similar manner, except that measures have to be taken to prevent the lead from sliding down the hip, which is usually done by nailing the sheets of lead at the top. Another means of rendering a hip water-tight is to provide specially cut pieces of lead, zinc, or copper, termed **soakers,** which are laid under the slates and lap over each other.

37. Secret Gutter Along Hip.—Another method of finishing a hip is illustrated in section in Fig. 17. This consists in the construction of a **secret gutter** of metal along the top of the hip, as shown at *a*. In British practice gutters in such a position are formed of lead or zinc, but in America tin is frequently used. The width of the metal sheets forming the gutter is about

8 inches, and the width of the gutter itself is regulated by the thickness of the ridge piece and consequently will never exceed

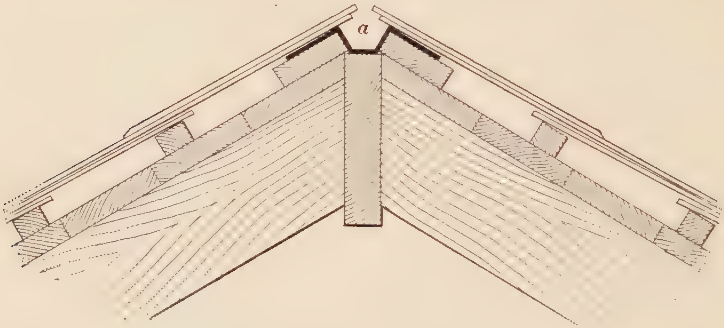


FIG. 17

2 inches. It is customary to nail the sheets on both edges, as the effect of any expansion or contraction can be taken up by the gutter itself, which is merely dressed against the woodwork and not fixed in any way at this point. It will, of course, be necessary to provide for the drainage of the water discharged by the gutter at the bottom of the hip.

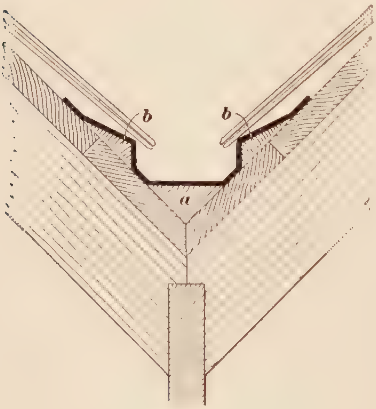


FIG. 18

38. Valleys in Slated Roofs. Valleys in slated roofs may be treated as shown in Fig. 18, where a small valley is constructed at the intersection of the two roof slopes. A small fillet *a* is provided to fit into the angle at the bottom of the gutter, and tilting fillets *b* are provided on each roof slope in order to give the necessary tilt to the slating A result quite as satisfactory as that afforded by the construction of a gutter can be obtained by the use of soakers under the slates, and this method of finishing valleys is frequently adopted.

39. Verges in Slated Roofs.—If at the end of a pitched roof, the end wall beneath is not carried up to form a finish, then the roofing material is carried over the top and an inch or so beyond the face of the wall; this is termed a **verge.** In finishing the verge of a slated roof, a double course of slates should be provided in a similar manner to that at the eaves, and the slates should be well bedded and pointed in cement.

40. Slating Curved Surfaces.—In slating curved surfaces, very great care must be taken. Commencing at the lower course, with slates from 6 to 10 inches wide, the size must gradually be reduced until a slate 2 inches in width is reached. This is about the smallest size that will safely cover a nail hole and keep the weather from affecting it. Even with this width the upper courses should be well bedded in slater's cement, which is generally composed of paint skins and refuse lead, as should also all hips, ridges, and joints round chimneys, bulkheads, gables, and parapet walls.

41. Repairing Slated Roofs.—The broken slate is removed by means of the ripper, and a new slate is inserted; but as the new slate cannot be nailed, on account of the slates already fixed on the roof being in the way, it is secured by means of lead or copper tacks, which are narrow strips of metal about $\frac{1}{2}$ inch wide hooked over the head of the slate below, as at *a*, Fig. 19. The new slate *b* is then inserted and the lead or copper tack is turned up over its tail, as shown at *c*. There should always be two tacks to each new slate inserted.

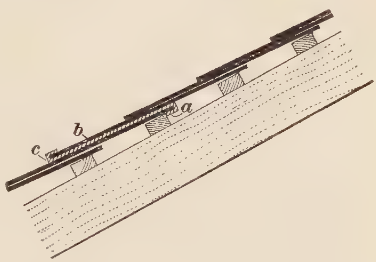


FIG. 19

STONE COVERINGS

42. In many districts in the British Isles where stone is plentiful and of such a character that it can be split with comparative ease into slabs from $\frac{1}{2}$ inch to 1 inch in thickness, it is

used as a form of roof covering, the slabs being termed **stone slates.** In consequence of their generally pleasing colour, stone

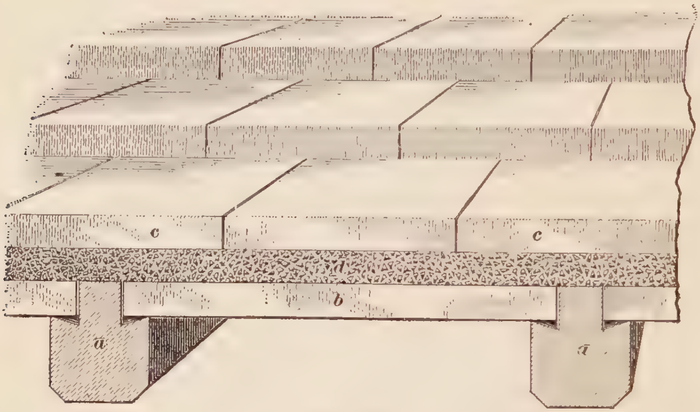


Fig. 20

slates, when obtainable in the near locality, are much favoured by architects. Their weight is, however, very considerable, and extra strong roof timbers have to be provided.

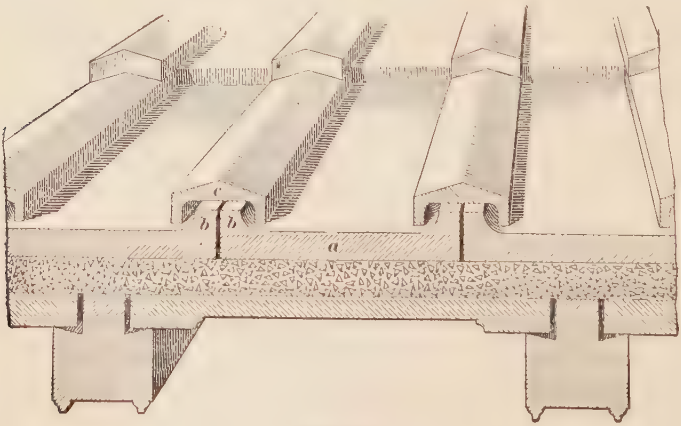


Fig. 21

Stone slates are obtained in various sizes, and then sorted and laid in diminishing courses from eaves to ridge in a similar manner to slates. Sometimes before the slates are laid the

space between the slate battens is filled with lime mortar, which is carried by laths extending between the rafters. The stone slates then, in addition to being nailed, are bedded in the mortar and pointed with the same material.

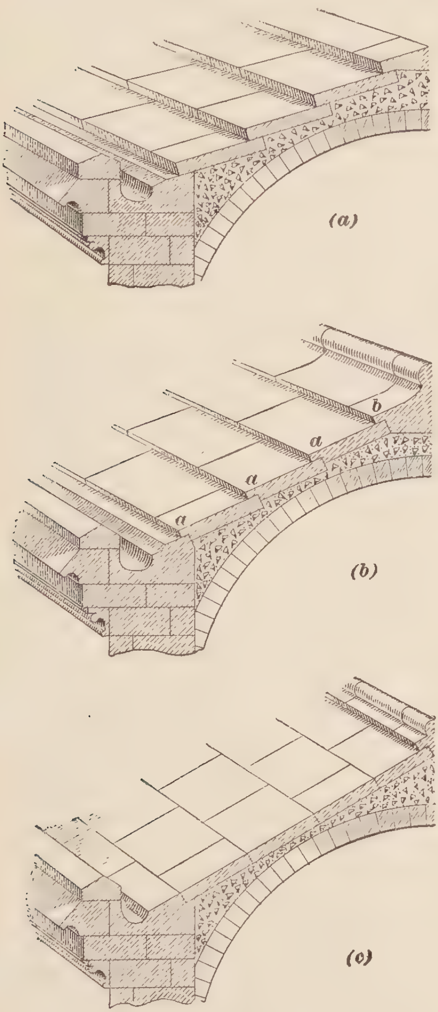


FIG. 22

43. Sawn-Stone Slabs. Sawn slabs of stone are sometimes used for covering small vestibules, porches, and the roofs of churches and other monumental buildings. The roofs may be almost flat or pitched. Large slabs are used for flat roofs, and small slabs for pitched roofs. They may be laid either with lap or butt joints on a filling resting on the supports beneath.

In Fig. 20 is shown the construction of a flat roof, which may be applied either to barrel vaulting or stone bearers, the latter being shown. The bearers *a* are rabbeted to receive the ceiling slabs *b*, and the roof slabs *c* are laid and bedded in cement concrete *d*. Bearers of stone, however, have very little transverse strength, and can be used only over very short spans. For long spans, steel joists encased in concrete are more suitable.

The Greeks and the Romans had a similar method of supporting and laying roof slabs, with this difference: the slabs were cut, as shown at *a*, Fig. 21, so that they formed a channel with fillets *b* on each side, and the joint was covered with a cap *c*.

44. Slabs Overlapping and Bedded in Cement.—For pitched roofs, slabs may be laid, as shown in Fig. 22 (*a*), each overlapping the one beneath, and bedded in cement on the filling over the barrel vault.

A better construction is shown in Fig. 22 (*b*). The slabs are cut with a rabbet and a lap joint *a*; the cap, or ridge, stone is made with a rabbet and a lap joint *b* on each side at the edge of the wing, the same as the lower edge of the slabs. The advantages gained by the use of the rabbet and the lap joint are, that the stones, if they should work loose, cannot slip from the roof as they would if laid with a simple lap, and that there is no open vertical joint for the passage of water, as in the method shown in Fig. 22 (*c*), where a plain butt joint is adopted, an arrangement which cannot be recommended.

45. Stone Gutters.—The gutters in the forms of roofs just described are cut out of a single stone, as at *a*, Fig. 23. The water is carried from the gutter through a channel *b*, cut in a stone extending the full width of the wall, and discharges into the rain-water pipe head *c*. This method of cutting a gutter out of a single stone can be adopted only for short lengths of roofing, as in the case of a long length the gutter will not be sufficiently large to carry away the water. Moreover, stone gutters are often porous and in a severe frost are liable to be seriously damaged. A sounder method in the case of a large roof is to carry up the parapet to the requisite height and provide a lead gutter on proper bearers and with the necessary drips.

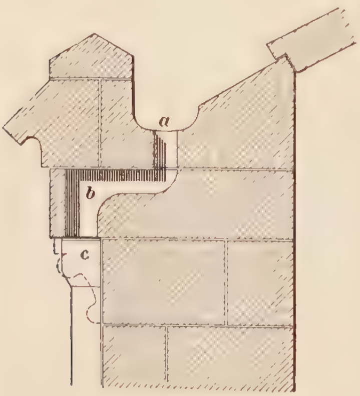


Fig. 23

46. Self-Supporting Stone Roofs.—Roofs for turrets, spires, and domes, when built of stone, are self-supporting and complete without the addition of framing. In Fig. 24 (*a*) are shown a half-elevation and a half-section of a conical roof. The beds of the joints are kept horizontal, while the vertical joints radiate from the centre of the plan, as shown in Fig. 24 (*b*), the dotted lines indicating the manner in which the joints in one course break joint with those in the course above and the course below. The outer stones used for such roofs may be constructed as shown in (*c*), to the suggestion of a lap, or they may be rabbeted and lapped, as in (*d*). The terminal or finial should commence at a point where the ordinary form of block becomes too small to be constructed conveniently, and should preferably be of a single piece of stone.

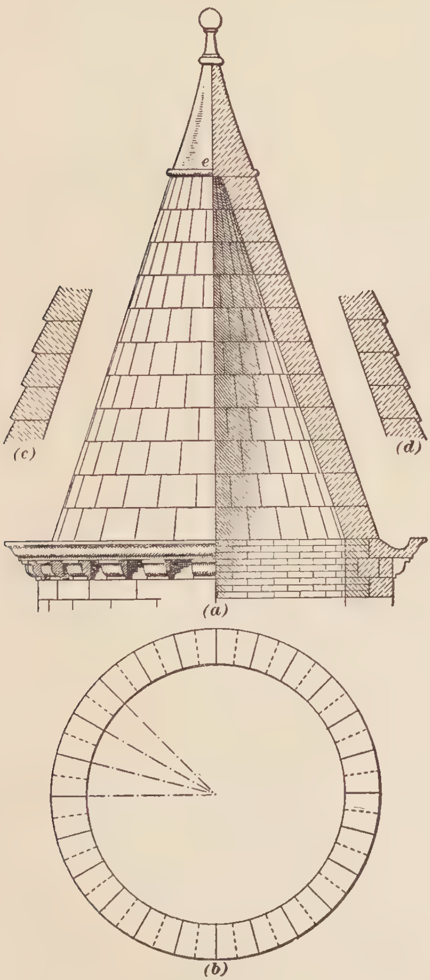


Fig. 24

In the case of spires, the bed-joints of the stones, instead of being horizontal, are often made at right angles to the slope of the spire. The thickness of masonry

in such structures is very much less than is generally supposed, a thickness of from 6 to 9 inches being sufficient for all ordinary cases. In domes, the thickness varies considerably in accordance with the form and size of the dome.

TILING

47. Classification of Tiles.—The tiles in most general use are known as *plain tiles, pan tiles, Roman tiles*, and *interlocking tiles*. In dealing with the utilization of tiles for roofing purposes, a grouping in two broad classes is possible, the first class being the plain tiles, which are laid so as to have a double thickness all over the roof, and the second class including the pan, Roman, and interlocking tiles, which provide only a single thickness except at the points where the laps occur.

48. Laying Plain Tiles.—Plain tiles are usually laid on battens or tile laths that are nailed to the rafters in a similar manner to the battens used in slating. The tiles may either be nailed to the battens or merely hung on by the nibs with which most modern tiles are provided, or, in accordance with a practice very general at one time, they may be hung on oak pins driven through the nail holes. Where tiles are nailed fir battens about 2 inches by 1 inch in size will be required, but where they are hung by the nibs, $1\frac{3}{4}'' \times \frac{3}{4}''$ battens will be sufficient, or $1\frac{1}{4}'' \times \frac{1}{4}''$ oak laths may be used. Sometimes the tiles are nailed only at intervals of several courses, but they should always be nailed at the verges, hips, valleys, and eaves. The nails used are either of copper or of iron. In the best class of work the battens are not placed direct upon the rafters, but boarding and felt are provided. There is no doubt that this forms a better roof than one with battens only, but there is naturally a considerable increase in cost.

49. Lap and Gauge.—The gauge of tiling is determined in a similar manner to that of slating, the gauge being half the amount obtained by subtracting the lap from the length of the tiles. In obtaining the gauge of tiles, the full length of a tile

is taken; there is no deduction from the length on account of nail holes as in the case of slates, the lap being the amount by which a tile covers the second one below it. Thus, in a tile $10\frac{1}{2}$ inches long, if the lap is $2\frac{1}{2}$ inches the gauge is

$$\frac{10\frac{1}{2} - 2\frac{1}{2}}{2} = 4 \text{ inches}$$

A lap of $2\frac{1}{2}$ inches is usually considered sufficient, although sometimes a lap of 3 inches, giving a gauge of $3\frac{3}{4}$ inches, is specified.

The number of tiles required to cover any particular surface may be obtained by dividing the area of the surface in question by the exposed area of a tile, which is the margin multiplied by the width, a further allowance, varying in accordance with the character of the roof, being made for cutting. It should be noted that the margin is equal to the gauge.

50. Tiles Hung From Boarding.—A method which constitutes a cheap and fairly satisfactory substitute for boarding and battens is to use feather-edged boarding, which, being thicker at one edge than the other, when laid with the thicker edges uppermost forms a series of ridges from which the tiles are hung. This method is shown in Fig. 25. The boards, which are 4 inches wide and $\frac{3}{4}$ inch thick at one edge and $\frac{1}{8}$ inch thick at the other edge, are shown at *a*, and the tiles at *b*. Before commencing to lay the boards, the gauge must be set out from the eaves to the ridge, as the laying must begin from the ridge, and if care is not taken to arrange and, if necessary, to cut the boards, it may be found that they do not work out evenly at the eaves. It is necessary to provide a double course at the eaves in a similar manner to the method adopted in slating. For this purpose, special tiles are made

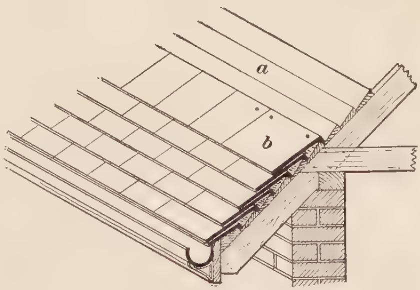


Fig. 25

having a width equal to that of an ordinary tile but a length of only $6\frac{1}{2}$ inches.

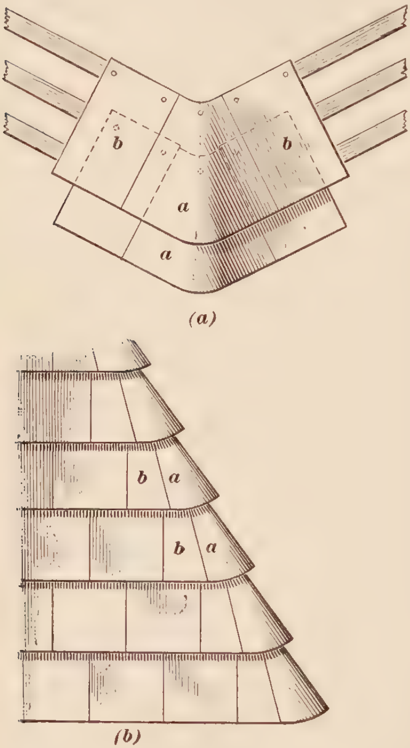


FIG. 26

51. Special Tiles for Hips and Valleys.—The fixing of ridge tiles is simple, as they are merely bedded in mortar or cement. Specially made tiles are often used for hips. The bonding of these tiles with the ordinary tiles of the roof is shown in Fig. 26 (*a*), and the appearance of the tiles when laid is shown in Fig. 26 (*b*), *a, a* being the hip tiles and *b, b* the ordinary roofing tiles. For valleys, although lead gutters are sometimes adopted, it is a better arrangement to use specially made valley tiles, the method of laying of which is illustrated in Fig. 27. It should be noted that valley tiles are not nailed.

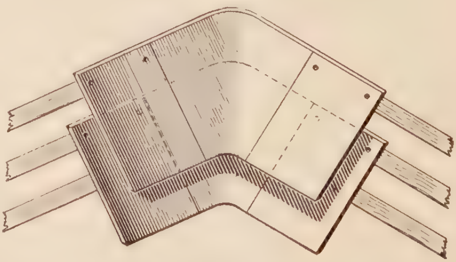


FIG. 27

52. Tile Verges.—In the construction of tile verges it is well to keep back the battens or boarding $4\frac{1}{2}$ inches from the face of the brickwork. Each tile is thus fixed only by a single nail, but this is counterbalanced by the fact that the tile for the remainder of its width is well bedded in a thick layer of mortar provided to

make the verge weather-tight. It is an almost invariable practice to bed a course of tiles on the top of the wall that is to receive the ordinary tiling of the roof. An illustration of a common method of forming a tile-verge is given in Fig. 28 (*a*) and (*b*). A line of tiles with the nibs cut off are shown to be provided at *a*. They are laid, butt-jointed, bedded in mortar; have an inward tilt of about ½ inch in order to prevent the water from flowing off the verge, and project about 2 inches from the face of the wall. On the top of this course of tiles is a thick layer of mortar *b*, equal to the depth of the battens, and on this layer the ordinary tiles of the roof are bedded.

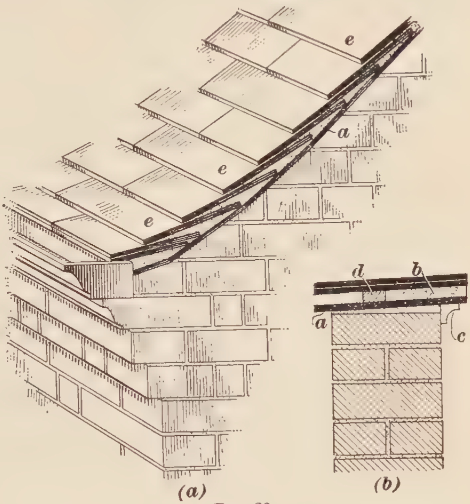


Fig. 28

53. It is customary to run a fillet or small cement moulding into the angle formed by the junction of the lowermost course of tiles with the face of the wall. This is shown at *c* in (*b*), which is a section taken through the face of the wall and the tiles at right angles to the rake of the roof. The tile battens are shown at *d* in (*b*).

It will be observed that the tiles shown at *e* in (*a*) are wider than the others. They are specially made and are equal in width to a tile and a half. Tiles of this kind should always be provided at alternate courses at all verges, and should also be used at hips and valleys, for, in these positions, they have to be cut, and it is well to ensure that all tiles are not less in width than half a tile.

54. Use of Ornamental Roofing Tiles.—A roof may be covered entirely with ornamental roofing tiles, but this is seldom done.

The commonest way of using such tiles is to lay them in comparatively narrow horizontal bands in order to relieve the appearance of the ordinary plain tiling. As, however, the lower edges of the tiles are cut to a special form during the course of manufacture, the portions of the roof thus covered do not offer so sound a resistance to the weather as where ordinary tiles are used.

55. Covering Conical Roofs With Tiles.—Tiles for conical roofs must be made to suit the requirements of each case. It is, however, generally possible to use a uniform size for four or five courses, and a smaller size for the next four or five courses, and so on until the base of the finial is reached. The laying of tiles on conical roofs requires to be conducted with great care, as, if the tiles are not laid regularly, the roof will not look well. Further, after the completion of the work, it is often impossible to reach such roofs without the construction of special scaffolding, and thus the remedying of any defect or leakage will be an expensive operation.

56. Laying Pan Tiles.—Tiles of curved form, termed **pan tiles,** usually 14 inches long and 9 inches wide, are used to a very considerable extent in roofing cottages, farm-buildings, outhouses, and similar structures. Where the roof is without ceiling, light, if necessary, may be introduced by the use of glass tiles, exactly similar in form and size to an ordinary pan tile. An essential difference between the laying of plain tiles and pan tiles is that in the latter case the lap is the distance by which a tile extends over the one immediately below it, and not the distance over the second tile below it, as in the case of plain tiles, where a double thickness of tiles is provided. Thus the gauge of pan tiles is simply the length of a tile minus the amount of the lap. There is no double course at the eaves.

57. Hanging Pan and Other Tiles.—Pan tiles are hung by nibs on battens similar to those used for plain tiles, the lap of the tiles being about 3 to 4 inches. They should be well bedded in mortar at the eaves, and the joints throughout the roof should be pointed on the under side with hair mortar. Pan-tile roofs differ from roofs of other forms of tiling or of slating in that flashings of metal round openings or against walls are rarely

used. By reason of the curved form of the tiles, it is found that cement fillets give rather better results than metal flashings, and are, of course, very much cheaper.

For ridges, hips, and valleys it is customary to use specially made half-round tiles. These should be well set in mortar, and are sometimes nailed to the woodwork of the roof. Roman tiles and the several forms of patent interlocking tiles are hung in a similar manner to pan tiles, the gauge being the length of a tile minus the lap. The tiles of both classes are usually fastened with nails.

SHINGLE ROOFING

58. Wooden Shingles.—Wooden shingles are used for roofing to some extent in the British Isles, particularly in the construction of spires, turrets, and other similar forms of steep-pitched roofs, and are largely used in Canada and the United States, although shingle roofs are admittedly of an inflammable character. Shingles are made by sawing or splitting wood, cleft shingles being preferable to sawn shingles, as, by the operation of splitting, continuous fibres throughout the length of the shingle are ensured. In the British Isles, shingles are usually of oak, and form a roof covering of a fairly durable character. In America, the woods from which the best shingles are obtained are red cedar, white cedar, cypress, and white pine. Cypress and white cedar shingles, though the least used, are considered the most durable.

59. Sizes of Shingles.—The ordinary lengths of shingles are from 16 to 18 inches or from 24 to 27 inches, and the widths, from 3 to 7 or 10 inches. Thick shingles measure about $\frac{9}{16}$ inch, and thin shingles about $\frac{3}{8}$ inch, at the bottom. Shingles are wedge-shaped in section and $\frac{1}{16}$ inch thick at the upper end. Cleft shingles of English oak are from 12 to 16 inches long and from 4 to 8 inches wide. In the United States, shingles can be obtained cut to a uniform size or width. They are 4, 5, or 6 inches in width, and are usually dressed.

60. Gauge of Shingles.—Where roofs are in exposed situations, and long white shingles are used, a treble thickness of shingles

may be adopted, the lap in such a case being the distance which a shingle extends over the third one below it. The gauge is then obtained by deducting the lap from the length of a shingle and dividing the result by 3. Thus, under such conditions, the gauge for shingles 18 inches long laid to a 3-inch lap will be $\frac{18-3}{3} = 5$ inches, as shown in Fig. 29. Where a general thickness of two shingles only is adopted, as is the usual method in British practice, the gauge will be obtained in a similar manner to that in plain tiling, and will be half the difference between the lap and the length of a shingle.

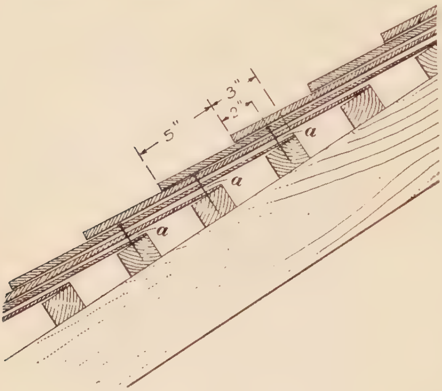


Fig. 29

61. Laying Shingles.—The methods of laying shingles generally in use are: (*a*) on battens similar to those employed in slating; (*b*) on boarding without felt; and (*c*) on battens and boarding with felt. The first method is undoubtedly the best, though it is generally used only on cheap buildings. In more expensive buildings, boarding is usually employed. This method, however, unless the ends of the roof are left open, prevents the free circulation of air under the shingles and causes them to decay quite rapidly.

62. Laying Shingles on Battens Only.—To lay shingles on battens without boarding, there should be from one to three roof boards, about 10 inches in width, laid along the eaves and valleys to receive a few of the first courses of shingles. The object of placing these boards in this manner is to protect the shingles should it become necessary to walk along the eaves to make repairs. If the valleys formed by the main roof and dormers are not very long, one board on each side is sufficient. The eaves course of the shingles should be doubled, and the

shingles should overlap the gutter about $1\frac{1}{2}$ inches. Each shingle is fastened with two galvanized iron nails, at a point about 2 inches above the upper line of the exposure or margin, which point coincides with the position of the batten below, as shown at *a* in Fig. 29. The heads of the nails are in this manner protected by the laps, and the shingles are further secured by the nails of each succeeding course passing through the heads of the previous course. If the gutter is built on the surface of the roof, the bottoms of the shingles should be placed well up above the overflow line.

63. Laying Shingles on Battens and Boarding.—Where boarding is adopted in addition to battens, the boards should not be set close together, as otherwise they would then prevent the passage of air, stop ventilation, and cause the shingles to decay. This process of decay arises from the warm air of the rooms below condensing when it comes in contact with the roof, making the material wet, or resulting in what is called *sweating*. It is also caused by capillary attraction acting through the bottoms of the shingles.

64. Use of Boarding, Felt, and Battens.—Where the ceiling line is required to follow the rake of the roof and it is essential that the boarding is laid with close joints, felt in addition is usually provided on the top of the boarding. This method of close boarding is, however, very undesirable for a shingle roof. When it is necessary, it is well to adopt a double series of battens, as there will then be no possibility of water collecting on the top of the boarding, and there will be more air space round the

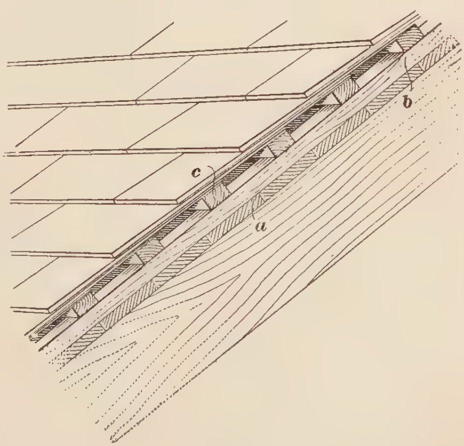


FIG. 30

battens. Fig. 30 illustrates this method, the boarding being shown at *a*. The first series of battens, which are spaced about 12 inches apart and run up the slope of the roof, are shown in elevation at *b*, and the second series of battens at *c*.

65. Ridges in Shingle Roofing.—There are several methods of finishing the ridge of the roof. One consists in laying over the last row of shingles but one a metal flashing, as at *a*, Fig. 31, which extends on each side of the ridge to the depth of the last row, after which the last row *b* may be laid and the ridge capped with a ridge saddle, $1\frac{1}{4}$ inches thick, of the same material as the shingles. The first side *c* is put on flush with the ridge, and the finished piece is put on with a lap of about $\frac{1}{2}$ or $\frac{3}{4}$ inch, as shown at *d*.

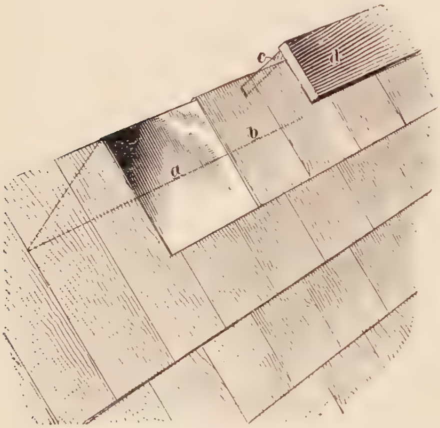


FIG. 31

66. Another method consists in the use of a wooden roll covered with metal in a similar manner to that employed in the case of a slated roof. This method is shown in section in Fig. 32. The ridge *a* is carried up slightly above the shingles, and the wooden roll *b* is well spiked to the ridge. After the shingles are laid, the roll is covered with tin or lead extending about 6 inches down the shingles on each side, as shown in section at *c*. To

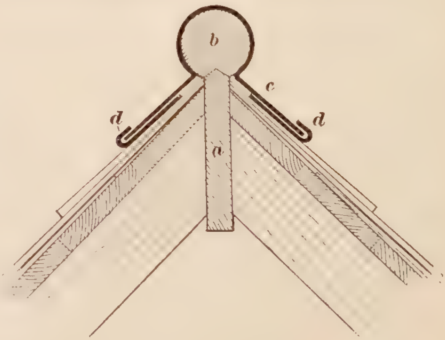


FIG. 32

prevent this metal covering from being lifted by the wind, strips of lead or tin, about 6 inches long and $2\frac{1}{2}$ inches wide, as shown at *d*, are nailed at intervals of about 2 feet along the roof under the flashing, and then turned up and dressed about 1 inch over the edge.

67. Hips and Valleys in Shingle Roofing.—In the construction of hips in shingle roofing a metal-covered roll similar to a ridge roll may be used, or a secret gutter, constructed in a similar manner to that shown in Fig. 17, may be adopted. In valleys, a gutter similar to that shown in Fig. 18 is often used. The use of soakers in both hips and valleys will produce very satisfactory results. The soakers most commonly used in the United Kingdom are of lead, but in the United States tin is often favoured. Zinc should never be employed where, as is generally the case in British practice, the shingles are of oak, for the gallic acid in that wood is quite capable of destroying the zinc.

68. Allowance of Spaces Between Shingles.—In laying shingles on a roof, the best results are obtained and their endurance, which is the chief point, is vastly increased by setting the shingles from $\frac{3}{16}$ to $\frac{1}{2}$ inch apart. This permits the water to drain off rapidly, secures quick drying of the roof, allows for expansion, and prevents buckling. Where narrow shingles are used, the joints should not be smaller than $\frac{1}{8}$ inch, while for shingles over 5 inches in width, from $\frac{1}{4}$- to $\frac{1}{2}$-inch joints should be allowed.

69. Shingling Conical Roofs.—For covering conical roofs, the shingles should be selected in three or four widths, the largest being about 5 inches wide at the gutter, and the smallest, at the top, 2 inches wide. In Fig. 33 the shingles, that are 5 inches wide, are laid to a height of four courses in the space indicated by the letter *a*, and those 2 inches wide to a height of four courses in the space *d*. The spaces *b* and *c* are occupied by shingles 4 and 3 inches wide, respectively.

To keep the shingles true to the radial lines, and the tails in line with the horizontal curves or courses running round the tower, a nail is driven into the centre of the apex post *e*, to which a cord is attached. The starting course is laid parallel

to the eaves, the next gauge is laid off, and a shingle *g* is tacked in place. The cord is held to a joint of the first course under the tacked shingle, and a line is drawn through the centre of the shingle *g* vertically; the cord is then moved to the outside corners at the bottom of the shingle, first at *h* and then at *i*. The side or taper lines *h j* and *i k* drawn in this manner will be radial to the centre of the apex, as shown by the plan *l*. A shingle, cut to the lines marked, will form a template for the first course. The 5-inch wide shingles should be laid first, then those which are 4 inches wide, and so on until each lot is used, a new template being made as often as the joints begin to come too close.

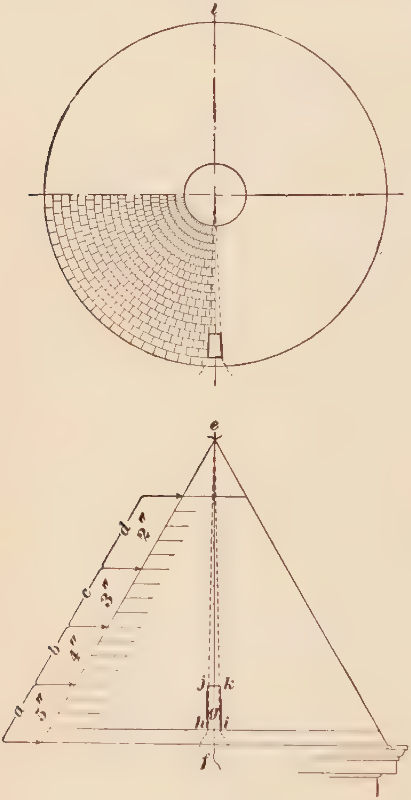


Fig. 33

This mode should be continued until the base of the finial is reached, when, if a wooden cap is to be used, the apex should be covered with a flashing of lead or tin. If, however, a sheet-metal finial is required, the flashing may be omitted.

GALVANIZED SHEET-IRON ROOFING

70. Preparation.—Galvanized iron is iron coated with zinc, the object being to protect its surface from the rapid oxidization that takes place when unprotected iron is exposed to atmospheric

influences. The zinc coating is applied to the plates after they have been heated and dipped in chloride of zinc, which acts as a flux, the plates having been prepared by cleaning and dipping in sulphuric acid. The coating should be uniform in thickness and should cover the entire surface.

71. Test.—To test the quality of galvanized iron, take a small piece of the iron, bend it double, and pound it down close; if no fracture is shown, the iron is of a good quality. A more severe test is to flatten it out again, and see if the material then shows signs of fracture. Samples may be tested for thickness of coating by greasing them and holding them over a gas jet; the amount of fusible metal flowing off will determine the character of each sample.

72. Corrugated-Iron Sheeting.—Galvanized iron in the form of **corrugated-iron sheets** is used largely for roofing, particularly in the Colonies. The iron sheets must be of good quality to withstand the process of corrugating, as otherwise they will crack. The corrugations are made by passing the sheets through rolls or by pressing them, the latter process making the most perfect and uniform corrugations. Sheets can be obtained from 5 to 10 feet long, rolled from sheets 3 feet 2 inches wide before corrugation, the width when completed depending on the number of corrugations, but being usually from 2 feet 3 inches to 2 feet 6 inches. The sheets used for roofing vary from 18 to 28 Birmingham wire gauge, the thickness of the lower-gauge sheets being about $\frac{1}{16}$ inch. For general work a 24 gauge is customary, although the use of lower-gauge sheeting is desirable in work of a better class. The width of the corrugations varies from 3 to 5 inches. If the thickness is constant, the smaller the corrugations the stiffer is the sheet, and the thinner sheets are thus usually rolled with small corrugations. A form of sheet commonly used has eight 3-inch corrugations.

73. Estimating Amount Required.—Corrugated-iron sheets are usually sold by the ton. The approximate number of sheets per ton, in accordance with the gauge and length, is given in Table III.

In calculating the amount of corrugated iron to cover a known area of roof, it is necessary to deduct the amount of the laps from the size of a sheet, this giving the area of the portion of the sheet which is exposed to the weather. By dividing the area of the roof by the exposed area of a sheet, the required number of sheets will be obtained, and then, by using Table III, the necessary weight of metal to be ordered can be ascertained.

TABLE III

APPROXIMATE NUMBER OF SHEETS PER TON

Gauge	Length of Sheets, in Feet					
	5	6	7	8	9	10
18	84	70	60	52	46	42
20	105	88	75	66	58	53
22	134	112	96	84	74	67
24	168	140	120	105	93	84
26	216	180	155	136	124	108
28	240	200	171	150	133	120

74. Fixing Corrugated - Iron Sheets. — For ordinary work, corrugated-iron sheets are carried by small purlins spaced at about 4 feet centre to centre and resting on small trusses placed from 8 to 10 feet apart. Small dwelling houses, such as cottages and bungalows, are sometimes roofed with corrugated iron. In such a case, if the ceiling line coincides with the slope of the roof, the sheets should be laid on boarding and felt ; the use of the latter is particularly desirable, as, without some non-conducting material, the room beneath will be very much affected by changes of the external temperature. The sheets are, of course, laid so that the corrugations run parallel with the slope of the roof. They should be arranged so as to have an end lap of from 4 to 6 inches, according to the pitch of the roof, that is, the flatter the pitch the greater the lap. They should also have a side lap of one corrugation.

75. Corrugated-iron sheets are usually fastened together by small bolts and washers spaced from 6 to 9 inches apart, there being a double row of bolts where the end laps occur, and they are secured to the timbers of the roof by 2-inch cone-headed screws and washers. Where the sheets rest on boarding, screws are used both to unite the sheets and to fasten them to the boarding. It is customary to put red lead between the head of the bolt or screw and the washer, with a view of making the joint weather-tight. The holes for the bolts and screws should always be made at the top of a corrugation, as at such a point there is the least danger of leakage of water through the roof. An illustration showing the method of connecting corrugated-iron sheets which have an end lap of 6 inches at a and a side lap of one corrugation at b is given in Fig. 34.

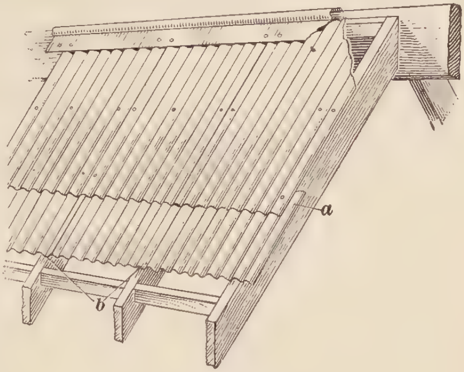


Fig. 34

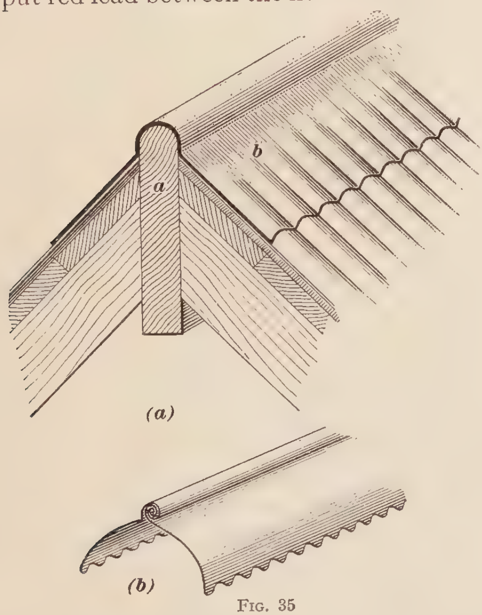


Fig. 35

76. Ridges, Hips, and Valleys in Corrugated-Iron Roofs. Ridges in sheet-iron roofing are usually finished as indicated in Fig. 35 (a), where the ridge a is shown to be taken through the

roof and the upper edge rounded off to take the galvanized ridge capping *b*, which is fixed to it by screws. The wings of the capping are shown to have corrugations coinciding with those of the roofing sheets. Hips are finished in a similar manner, with the exception that the capping must be plain, without corrugations. In Fig. 35 (*b*) is shown a common form of ridge capping which has both edges turned down and is scalloped to fit the corrugations in the sheeting. When this form of capping is used, the ridge does not require a rounded top.

Valleys are formed of plain sheets of galvanized iron, from 18 to 24 inches wide, having an end lap of at least 6 inches. Corrugated iron is cut to the proper angle and fitted over the valley, the corrugated sheets extending for a distance of about 6 inches over the plain sheets which form the valley.

77. Skylights in Corrugated-Iron Roofs.—It is often necessary to form openings for lighting purposes in corrugated-iron roofs. In such a case, the best method of construction is the insertion of specially made galvanized-iron skylights, either with fixed lights or constructed to open, whichever may be required. A light of this kind is prepared at the works, being fitted and riveted in a sheet of corrugated iron, and when fixed it constitutes a sound and water-tight arrangement. Fig. 36 illustrates a fixed skylight of this type, where *a* is the glass, *b* the frame into which it is fixed, and *c* the galvanized-iron corrugated sheet on which the frame is fixed.

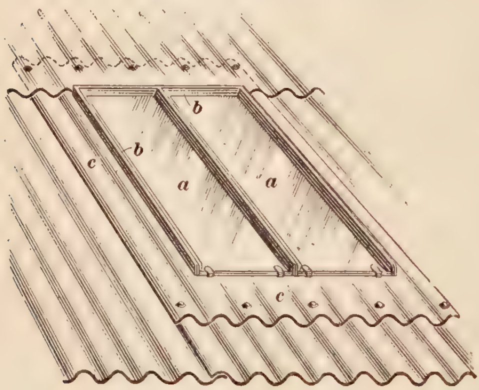


Fig. 36

Wooden skylights may be formed in corrugated-iron roofs, but it is difficult to make the joint next the corrugated-iron sheets water-tight.

78. Curved Corrugated-Iron Roofs.—Corrugated iron is extensively used for the construction of curved roofs. It is found that curved corrugated-iron sheets have very considerable stiffness, and they are often used for spans of from 10 to 15 feet without any tie, but the provision of a tie is desirable when the span exceeds 10 feet. Where a tie is provided, this is usually prevented from sagging in the centre by a light vertical rod, taken through the top of the roof and finished at the top with a solid head and washer, as shown at *a* in Fig. 37, and at the bottom with a bolt and nut, as shown at *b*.

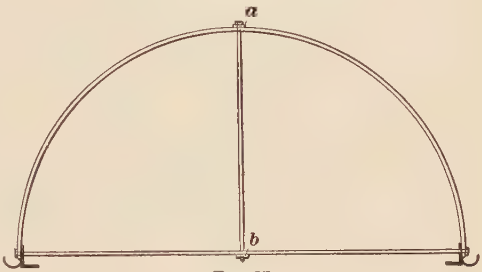
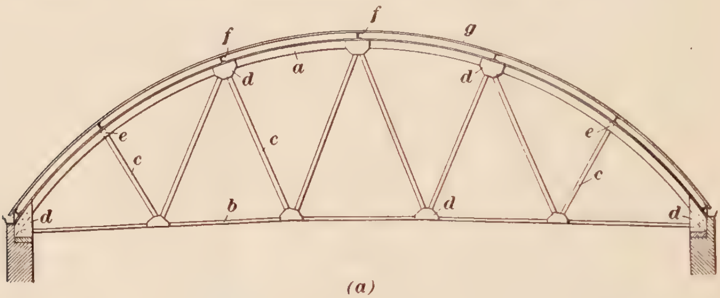


Fig. 37

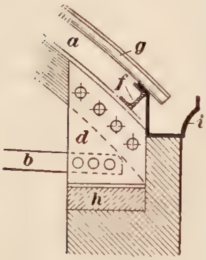
For spans longer than about 20 feet it will be necessary to provide struts. The number of these will depend upon the span of the roof, and they should be arranged so that the sheets are supported at intervals of from 6 to 10 feet round the curve of the roof. The ties should be placed about 8 feet apart. Where the span exceeds about 30 feet, it is desirable to provide curved steel principals in addition to the struts, thus forming proper trusses, but roofs of a much larger span are often constructed without principals.

79. An example of a truss for a corrugated-iron roof having a span of not less than 30 feet is shown in Fig. 38 (*a*). The angle iron forming the curved principal rafter is shown at *a*, the flat bar forming the tie at *b*, and the angle-iron bracing, which occurs throughout the truss, is shown at *c*. The connections between the members are made by double plates *d*, *d*, except in the two connections *e*, *e*, in which the angle irons *c*, *c* are slightly bent and run along the back of the curved principal, to which they are then riveted. In consequence, however, of the smallness of the scale the rivets are not shown. The plates at the supports are bent to angle-iron form in order to constitute a base for the

truss. The purlins *f* which carry the corrugated-iron sheeting *g* consist of small channel irons. The trusses are placed about 10 feet apart. A detail at the foot of the principal rafter is given at (*b*). The stone template on which the truss takes its bearing is shown at *h*, and the cast-iron gutter at the eaves at *i*. The



(*a*)



(*b*)

FIG. 38

other members shown are distinguished by the same letters as those in Fig. 38 (*a*). In cases where the roof is likely to be subjected to considerable wind pressure, it will be necessary to provide holding-down bolts at the supports. These will pass through holes formed in the bottom legs of the bent plates at the supports, and will be inserted in corresponding holes formed in the stone template. The holes will then be run and the bolts secured, either with lead or with cement grout.

80. Plain Galvanized Iron.—The use of galvanized iron for roofing is almost entirely restricted to corrugated sheets, as these have a much greater strength than plain sheets. If plain sheets are used, they must be joined by wood rolls running in the direction of the slope of the roof, the joints between the top and bottom of the sheets being made by welts in a similar manner to that customary in copper and zinc roofs.

It is a very general practice to paint galvanized iron, in order to increase the life of the material. The first coat of paint should consist of oxide of iron or oxide of zinc ; the remaining coat or coats may be of ordinary oil colour.

BLACK SHEET-IRON ROOFING

81. Black Sheet Iron.—Ordinary ungalvanized sheet iron, which is termed **black sheet iron** for the purpose of distinction, is used for roofing to some little extent in Canada and the United States, but is very seldom adopted in British practice. It is supplied cold-rolled and annealed, in thicknesses similar to those of corrugated iron. The sizes of the sheets vary from 72 inches by 24 inches for the lighter gauges to 84 inches by 30 inches for the heavier gauges. The sheets should be free from flaws or holes and uniform in thickness and ductility, and the painting of the roof to preserve it from oxidization is a necessity. Felt is not, as a rule, placed under iron, but its use, it should be observed, tends to make the roof more enduring, protecting it from gases underneath and from sweating.

82. Standing-Seam Sheet-Iron Roofing.—Sheet iron is usually laid with some form of standing seam, with or without a cap, on the interlocking pattern. **Standing-seam roofing** with cap is prepared by locking and seaming the sheets together, end to end, thus forming a continuous sheet the full length of the slope of the roof. The edges are then turned up 1 inch high and fastened with cleats *a*, as shown in Fig. 39. These cleats are made of metal 2 inches wide, having a bearing on the roof of 2 inches by $1\frac{1}{2}$ inches. The upstanding part of the cleats is cut down the middle, as shown at *b*, $1\frac{3}{8}$ inches, and one section *c* of the divided cleat is bent over the flange of the sheet *d* first laid. The edge of the sheet in the second row *e* is then turned up and placed against the cleat *a*, whose other half *b* is turned over this edge, as shown at *f*. The turned-up edges are then clamped or seamed up close and tight, and the cap *g* is put on. This cap

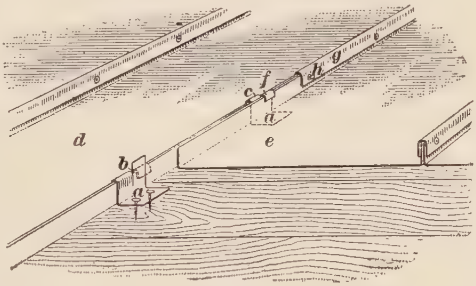


FIG. 39

should be clamped securely in place. Holes *h* are punched through the cap and flanges about 15 or 16 inches apart, and $\frac{1}{8}$-inch rivets are used to bind the parts together, washers being placed on each end of the rivets.

83. Double-Seam Sheet-Iron Roofing. — Another form of standing seam, known as **double-seam roofing**, is shown in Fig. 40. It is put up in rolls, the same as capped roofing, and the sheets are joined end to end by a single lock-seam. It may at once be seen that with this roofing no caps or fastenings of any kind are used, except the cleats *a*, which are nailed to the roof at the same centres as for the cap roofing. The sheets are turned up $1\frac{1}{4}$ inches on one side *c*, and $1\frac{1}{2}$ inches on the other side *b*. The $1\frac{1}{2}$-inch side is turned over the $1\frac{1}{4}$-inch side, as at *d*, and the whole seam is then turned over and down again, forming the double seam *e*, from which the roofing obtains its name. This method guarantees an enduring and water-tight roof

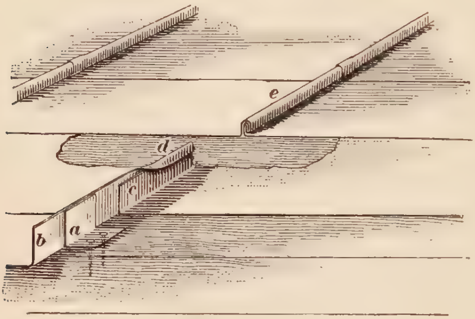


Fig. 40

TIN ROOFING

84. Roofing Plate.—**Roofing,** or **terne, plate,** made of soft steel or wrought iron covered with a mixture of lead and tin, is used to some little extent in the United States as a roof covering, but is very rarely adopted in the British Isles. The best American tin roofing sheets have the manufacturers' brand stamped upon each sheet, and those acquainted with this work are able to judge of the quality of the material from the brand.

85. Flat-Seam Tin Roofs.—There are two methods of laying tin-roof coverings in common use in the United States, namely: the *flat-seam* and the *standing-seam*. In the **flat-seam** method,

the sheets of tin are locked into one another at the edges, and nailed to the roof boards, as shown in Fig. 41, five or six nails being used to each of the sheets, which are usually 20 inches by 14 inches. The seams or welts are then flattened down with a wooden mallet and soldered. In Fig. 42 is shown the method of fastening the sheets with nails driven through the tin as at *a*, *a*, *a*; the nails, however, should not be placed more than 6 or 7 inches apart, and should be driven well under the seam, as shown in Fig. 41.

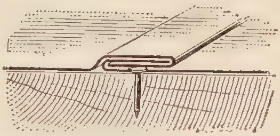


Fig. 41

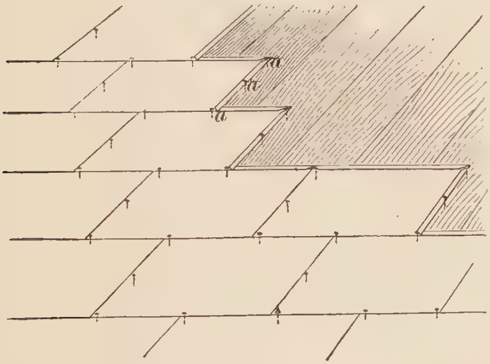


Fig. 42

86. Standing-Seam Tin Roofs.—In standing-seam tin roofing, the seams or welts running in the direction of the slope of the roof are composed of the turned-up edges of two adjoining sheets. The sheets of tin are first prepared in the shop by locking and soldering them together into long strips that will reach from the eaves to the ridge. Each strip is then placed on the roof, one edge being turned up about $1\frac{1}{4}$ inches and the other about $1\frac{1}{2}$ inches, as shown at *b* and *a*, Fig. 43. These strips are held in place with cleats placed from 12 to 14 inches apart. After the turned-up edges are double-seamed together and finished, the standing seam is about 1 inch high.

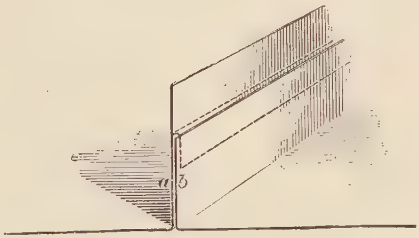


Fig. 43

87. Finishing the Seam.—The finished seam is shown in Fig. 44. The cross-seams, which must necessarily be flat seams, can either be single-locked, as in Fig. 45 (*a*), or double-locked, as in (*b*); in the latter case, the seams will not ordinarily require soldering.

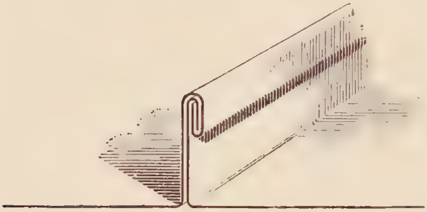
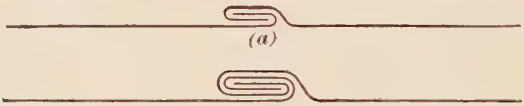


Fig. 44

Before laying the tin, the uneven edges of the roof boards should be smoothed off and the boarding covered with at least one thickness of sheathing paper, to protect the tin from any injurious



(*a*)

(*b*)

Fig. 45

vapours or gases that are likely to come in contact with its under surface. Knot holes in the boarding should be covered with galvanized iron.

COPPER ROOFING

88. Properties of Copper.—Copper is distinguished from all other metals by its peculiar red colour. When subjected to the influence of the atmosphere, however, it turns green. In country districts this green colour is light and attractive, but in London and large towns the copper takes on a dark dull colouring. Its resistance to corrosion when exposed to the atmosphere, combined with its lightness, gives it great value as a roof covering. Copper is very malleable, ductile, and tenacious, and is found in most countries, the principal mines being those on the shores of Lake Superior in the United States, and at Corocoro, Bolivia, South America. The copper mines in Cornwall and Devonshire are still productive, but not to any great extent.

89. Sheet Copper.—Copper is obtained from its ore by the following process: First, the ore is roasted or calcined; after

being roasted, it is melted in a reverberatory furnace, from which it issues in the state called *coarse metal*; this metal is then stamped and pulverized, passed through a furnace, and afterwards melted; the resulting metal is roasted and then refined. The copper is then cast into ingots and afterwards rolled into sheets, which are cut to market sizes.

90. Standards of Copper Roofing.—The size of British Common plates is 48 inches by 24 inches, but Scotch plates are 48 inches by 42 inches. For roofing work, however, special sheets from 5 to 8 feet in length and 3 feet in width are generally

TABLE IV

GAUGE AND WEIGHT OF COPPER

Birmingham Wire Gauge Number	Weight Per Superficial Foot		Weight of Common Plates		Weight of Scotch Plates	
	Pounds	Ounces	Pounds	Ounces	Pounds	Ounces
18	2	4	18	0	31	8
20	1	12	14	0	24	8
22	1	6	11	0	19	4
24	1	0	8	0	14	0
26		13	6	8	11	6
28		10	5	0	8	12
30		8	4	0	7	0

used. Sheet copper for roofing is annealed, and is thus comparatively soft and capable of being bent without risk of cracking. The gauge, weight per superficial foot, and weight per plate of copper used for roofing purposes are given in Table IV.

91. Tests of Sheet Copper.—The qualities determining the suitability of the sheets for roofing are ductility and strength and uniformity of gauge or thickness. The gauge must be as represented, and the sheet must be of the full weight in accordance with the gauge. When a piece is broken off, the fibre should present a bright, lustrous, and silky appearance if the copper is

of the best quality. The metal should also bear stamping into patterns without developing fractures.

92. Copper as a Roof Covering.—The advantages of copper as a covering for roofs are not so well known in the United Kingdom as they should be. There is an impression that copper is a very expensive form of roof covering, but such is not the case. No. 24 gauge copper costs about the same as 6-pound lead. Copper is very tough and exceedingly durable, for the green coating of verdigris which forms on the surface exposed to the atmosphere constitutes a protection to the other portion of the metal. Sheet copper of No. 24 gauge, as will be seen from Table IV, is only one-sixth the weight of 6-pound lead, and the expansion of copper under heat is only about two-thirds that of lead. Copper is particularly suitable for covering steeply pitched roofs and domes, for it remains unmoved in such positions, whereas lead, on account of its weight, coupled with the continual motion induced by expansion and contraction, is very liable to creep when laid on a pitched roof of large size.

93. Laying Copper on Pitched Roofs.—To ensure a thoroughly sound and lasting roof, the necessary provision must be made in the fixing to allow for the contraction and expansion of the metal. As the soundness of a copper roof depends very much upon the manner in which the material is laid, it is desirable that this work should be placed in the hands of a specialist firm. At one time it was customary to lay copper with a standing welt or seam, but this method is not now adopted. For pitched roofs, spires, and domes the usual form of jointing is by means of a flat welt similar to that shown in Fig. 41 in connection with tin roofs. In cases where the roof is in a very exposed position, the sheets may be additionally secured at the

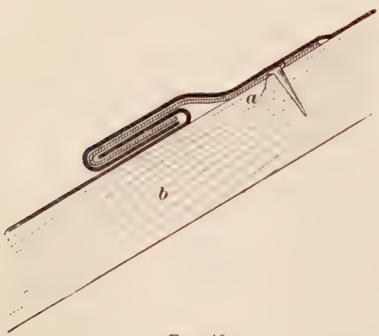
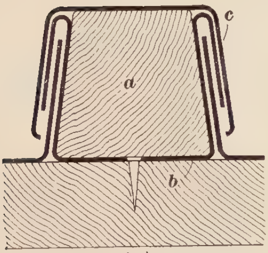


Fig. 46

joints by means of copper clips about $4\frac{1}{2}$ inches long and 2 inches wide, fixed to the roof boarding *b* at intervals of about 2 feet, as shown at *a*, Fig. 46. In pitched roofs, the welted form of joint may be adopted both for the joints running parallel to and for those running across the pitch of the roof. The soundness of the joints depends entirely on the proper overlapping of the metal. Solder is never used in this work.

94. Roll Joints. — Roll joints are occasionally adopted, although these are principally used on flat roofs. In this case the joints are formed by means of specially made wooden rolls about $1\frac{5}{8}$ inches high by $1\frac{5}{8}$ inches wide at the bottom, diminishing to $1\frac{1}{4}$ inches wide at the top, as shown at *a* in



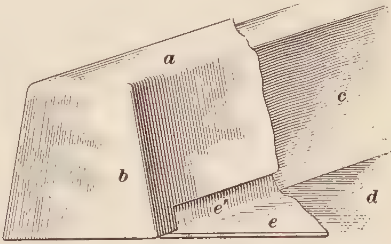


Fig. 47

Fig. 47 (*a*). The roll is prepared ready for the coppersmith, who nails the clip *b* under it before fixing it to the roof boarding. The clips are of copper about $7\frac{1}{2}$ inches long and $1\frac{1}{2}$ inches wide, spaced about 3 feet apart. The edges of the copper sheets are turned up against the roll on each side, and the clips are bent down and turned over these edges. The roll joint is completed by the addition of a continuous copper cap shown at *c*.

95. The copper caps have solid stopped ends formed without seams, as shown in Fig. 47 (*b*), where *a* is the cap and *b* the stopped end. The wooden roll is shown at *c*, the boarding of the roof at *d*, and one of the copper sheets of the roof at *e*, the portion of the sheet which is turned up to go under the cap

being shown at e'. The ridge roll should stand at least $4\frac{1}{2}$ inches above the roof boarding, be 2 inches thick, rounded on the top edge, and covered with a roll cap. The spacing of the rolls will depend upon the size of the sheets, the distance between the centres of the rolls being usually about 1 inch less than the width of a sheet; thus, if the sheets are 3 feet wide, the spacing will be 2 feet 11 inches.

96. Copper-Clipped Roll Joints.—Another method of making a joint of the roll form is illustrated in Fig. 48. It is sometimes adopted in American practice, and includes the provision of continuous copper clips or tingles *a*, *a* nailed to the roof before each sheet is laid. The edges *b* of the sheets are turned against the clips, and the left-hand sheet is bent over to form the lock *c*. The upturned edges of the sheets are then turned over in a roll, as indicated by the dotted lines, the completed metal roll *d* being thus formed.

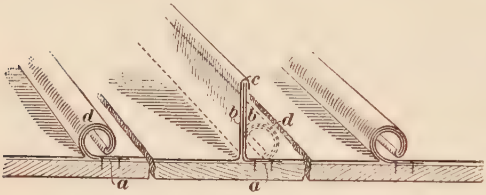


Fig. 48

A special and very economical method of forming the joints is illustrated in Fig. 49, and consists of the use of a conical roll *a* without a roll cap, the junction between the sheets being formed by means of a simple welt *b*. This joint has been found to give very satisfactory results.

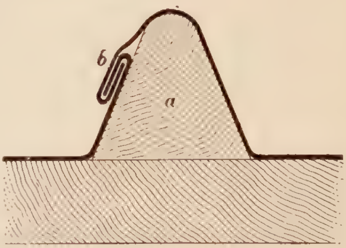


Fig. 49

METAL SHINGLE ROOFING

97. Use of Metal Shingles.—Metal shingles, or tiles, as they are sometimes called, are used to a very considerable extent in Canada and the United States, and are not infrequently adopted in the United Kingdom. Such shingles may be made of tin, zinc,

galvanized iron, copper, or bronze. In British practice, copper is the customary material, but in America shingles of less expensive metals are largely used.

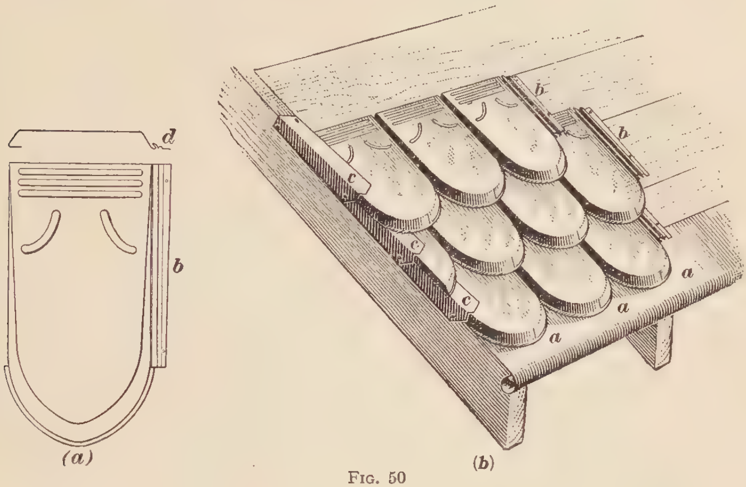


Fig. 50

98. Forms of Metal Shingles.—A type of metal shingle, used to some little extent in America, is given in elevation in Fig. 50 (*a*), and the method of laying shingles of this form is shown in

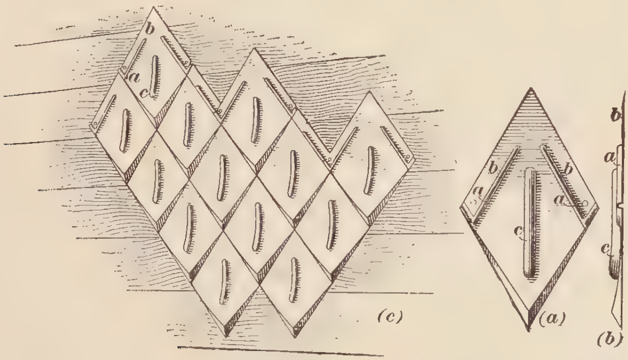


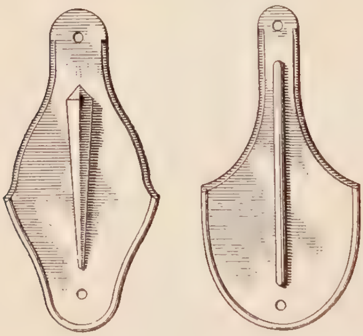
Fig. 51

Fig. 50 (*b*). The shingles are furnished on one side with a flange *b*, through which they are nailed. This flange is specially formed, as shown in section at *d* in (*a*), with a view of preventing water from finding its way by means of capillary attraction between

the joints. In laying shingles of this type the flashing for the gutter should be carried up about 6 inches under the shingles, as shown at *a* in (*b*), in which illustration the gutter is not shown. The method of flashing up the rake of the wall is shown at *c*.

99. Diamond-Shaped Shingles.—What are known as **diamond-shaped shingles** are shown in Fig. 51 (*a*), (*b*), and (*c*). The fillet *a* on the two upper flanges forms a water-tight joint, with a very economical lap. The shingle is nailed through the lower edge of the flange *b* on each side. The central longitudinal rib *c* is provided in order to impart rigidity and add to the appearance. It will be noticed that with these shingles, the laying may be commenced from the left-hand or right-hand side of the roof, according to convenience.

100. Leaf-Shaped Shingles.—Forms of shingles or tiles which are used to a very considerable extent on important buildings both in the United Kingdom and abroad are illustrated in Fig. 52 (*a*) and (*b*). These are generally made of stamped copper, and are about 16 inches long by 9 inches wide. They are particularly suitable for use on curved surfaces, and are frequently employed for the covering of domes, the shingles in such cases being made to diminish in size from the base to the crown of the dome. They are secured by screws to battens or boarding. The first portion laid should be set out on a centre line extending from the base to the top of the dome or roof, as if the alinement is not correct the appearance of the roof will be bad. The cappings to the ridges and hips can be constructed without wooden rolls, as, if the metal is of similar character to the shingles, it will be sufficiently strong in itself. Many other types of leaf-shaped shingles, to suit the design of the building, can be obtained from manufacturers.



(*a*) (*b*)

FIG. 52

SNOW GUARDS

101. Use of Snow Guards.—Snow guards are sometimes used on pitched roofs in order to prevent snow from sliding into and clogging the gutters, or, where there is no parapet, from falling over the edge of the roof and damaging skylights in roofs at a lower level. It is not generally necessary to provide snow guards to roofs in the United Kingdom, except in the case of buildings in exposed localities, but in North America the use of such arrangements is extensive.

102. Forms of Snow Guards.—The guards generally used in Canada and the United States consist of arrangements of galvanized-iron or copper wire, which, when fixed, stand up about 2 inches above the roof and prevent the snow from sliding. Two forms of snow guards are shown in Fig. 53 (*a*) and (*b*). The guard (*a*) is suitable for metal roofs with welted or seamed joints, and is secured under the welt by a galvanized-iron nail driven through the loop. The guard (*b*) is used for slate or shingle roofs, and is fixed by means of a spike driven between the joints of the slates or shingles into the roof boarding. In each form of snow guard, the twisted loop stands up about 2 inches higher than the face of the roof covering. Snow guards of this character are occasionally used in the United Kingdom.

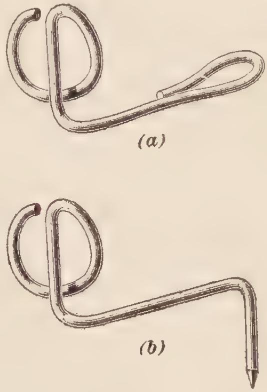


Fig. 53

103. British Snow Guard.—The form of snow guard chiefly used in British practice is illustrated in Fig. 54, in elevation in (*a*) and in section in (*b*). It consists of a light galvanized-iron wire lattice railing *a*, about 9 inches in height, placed about 2 inches above the roof, and secured and stiffened at intervals of 5 feet by standards, each one of which is connected to the

roof by iron stays, as shown at *b* in (*b*). Instead of the standards and ties, iron brackets are sometimes used, one leg of the bracket

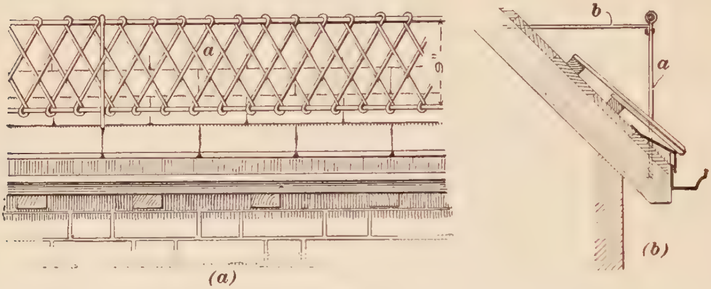


FIG. 54

being secured to the roof, and the other, which is turned up at an acute angle, acting as the support to the wire framing.

COVERINGS FOR FLAT ROOFS

METHOD OF FORMING FLAT ROOFS

104. The preceding portion of this Section has treated of the covering of roofs which have a slope such that water flows off easily. When, however, the slope is so slight that the surface of the roof is almost flat, it is necessary to adopt special methods of forming the joints, as otherwise the roof will not be watertight. As indicated in Table I, the only materials which can be laid with a very flat slope are lead, zinc, copper, tin, asphalt, and different forms of composition roofing. Roofs which are laid with the slightest possible amount of pitch are usually termed flats.

105. Rolls and Drips in Flat Roofs.—In the construction of a flat in lead or zinc it is necessary to form the joints running in the direction of the slope by means of rolls, and the joints running in the reverse direction across the slope by means of drips, the roof being stepped at these points to the extent of about 2 inches. When the roofing consists of copper or tin, materials which do not expand under heat to the same extent as lead or zinc, it is

possible to dispense with rolls and drips, but the work will be sounder if they are provided. Asphalt and composition roofs are always constructed in one plane surface, without rolls or drips.

106. Materials for Flat Roofs.—Although the use of lead has not been alluded to in dealing with pitched roofs, it must not be supposed that this material is never used on roofs of this character. As has already been stated, lead was very largely used throughout the Middle Ages as a roofing material for important buildings. But at the present time, although it is employed to some extent for the roofs of churches, the fact that trouble may arise from the creeping of the lead, if it is laid on a steep slope, restricts its use, and, consequently, other materials are generally preferred, the adoption of lead being practically confined to flat roofs. Zinc is hardly ever laid on a pitched roof, for the reason that if a relatively cheap material of this kind has to be adopted, better results will be obtained by the use of corrugated iron or some form of composition. Of the other materials suitable for flat roofs, the use of copper with relation to pitched roofs has already been described. Asbestos and ruberoid can also be used on flat as well as on pitched roofs, though they are more suitable for the former.

SHEET-LEAD ROOFING

107. Roofing Lead.—**Lead,** the softest metal in general use, is extremely pliable, very malleable, flexible, and heavy, but is lacking in tenacity and elasticity. It is found mostly in combination with other ores, and is obtained in Derbyshire, Germany, the United States, and the southern part of Spain. It is reduced from an ore called *galena*, by roasting or smelting in a reverberatory furnace furnished with long flues, to catch the particles of lead precipitated by the fumes. *Sheet lead* is either cast or milled. *Cast lead* is thicker and slightly heavier than milled lead, and has a harder surface, but, being liable to flaws, such as sand holes, etc., and irregular in thickness, it should not be used if lighter than 6 pounds per square foot. The lead on old churches and similar buildings is cast lead, but this is very much thicker

than the lead in general use at the present day. *Milled lead* is rolled thin, is more uniform in thickness than cast lead, bends easily, and when worked gives neater and better results. The lead used for ordinary roofing purposes is generally of this kind.

108. **Designation of Sheet Lead.**—Sheet lead is always specified and designated by its weight per square foot ; for example, sheet

TABLE V

WEIGHT AND THICKNESS OF SHEET LEAD

Weight Per Square Foot Pounds	Thickness of Sheet Inch	Weight Per Square Foot Pounds	Thickness of Sheet Inch
1	·017	7	·118
2	·034	8	·135
3	·051	9	·152
4	·068	10	·169
5	·085	11	·186
6	·101	12	·203

lead weighing 6 pounds per square foot is called **6-pound sheet lead.** Table V gives the thickness and approximate weight of

TABLE VI

WEIGHTS OF LEAD FOR VARIOUS POSITIONS

Position	Weight Per Square Foot Pounds
Main gutters	7 to 8
Flats	6 to 8
Hips, valleys, and ridges .	6
Flashings and aprons . . .	5
Soakers	4

sheet lead, which is supplied in sheets varying from 25 feet to 35 feet in length and having a width of either 7 or 8 feet.

109. Weights of Lead in General Use.—The weights of lead for different situations are given in Table VI. They vary in accordance with the extent of wear or exposure to which a roof is likely to be subjected, the durability of lead used in gutters and flats, for instance, being subjected to much more severe tests than that of lead used for flashings.

110. Laying Lead on Flats.—It will be seen from Table I that the slope of a lead-covered flat should not be less than 2 inches in 10 feet, although the slope is often kept as low as $1\frac{1}{2}$ inches in 10 feet. A slope of 3 inches in 10 feet is more desirable; and can usually be arranged without difficulty in the case of flats. The roof boarding upon which the lead is placed should be laid with the necessary fall, which is arranged by the provision of timbers called furrings, specially cut to give the required fall. These timbers are usually about the same thickness as the joists, and may run either transversely or in the same direction as the joists, the latter being the easier arrangement to carry out, as the furrings can in such case be cut to the same size. By the other method the longitudinal joints in the boarding are parallel with the slope, which is a very desirable arrangement.

111. Method of Furring.—The method of furring for a flat of about 20 feet span is shown in Fig. 55, in which *a* represents one of the fir joists carrying the flat and *b*, *b* indicate the furrings spiked on the top of the joist. The boarding is shown at *c*, the lead on the top of the boarding being indicated by a thick line.

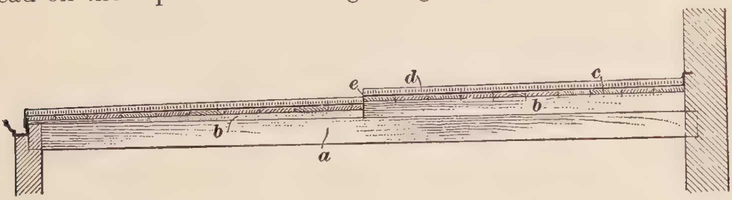


FIG. 55

One of the rolls, shown in elevation, is at *d*, and a drip is at *e*. When the span of the flat is considerable, it is a general practice either to slope the joists, or, if they run in the reverse direction to the slope of the roof, to arrange them at different levels. By such means it is possible to avoid excessive furring.

112. Boarding on Lead Flats.—The boarding on lead flats should be either 1 inch or $1\frac{1}{4}$ inches in thickness, rough or unplaned boards being generally used. If they are tongued together, the groove and the tongue should preferably not be in a central position, but closer to the bottom of the boards, as shown in Fig. 56, in which *a* is the groove in the right-hand board, and *b* the tongue in the left-hand board fitting into the groove. The reason for this is that if a good thickness of wood is provided above the groove the edges of the boards are less likely to curl up and cause irregularity on the surface of the flat. Sometimes roofing felt is laid on the top of the boards before the wood rolls are fixed. This acts as a non-conductor of heat, and therefore its provision is desirable, but by reason of its relative softness the lead cannot be dressed down upon it in such a satisfactory manner as upon plain boarding, and this is in some cases objectionable.

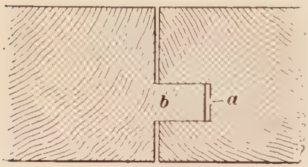


Fig. 56

113. Joints in Lead.—Lead should not be used in larger sheets than about 10 feet long and 3 feet to 3 feet 6 inches wide. The spacing of the wooden rolls depends on the width of the sheets, and will generally be about 8 inches less than the width of a sheet. The rolls are usually made of 2″ × 2″ material, and the lead is dressed over as shown in Fig. 57, in which *a* is the wooden roll, *b* the boarding to which the roll is spiked, *c* the underneath sheet which is carried a little beyond the summit of the roll, and *d* the upper sheet, which must be carried over the top of the roll at least as far as shown by the hard black line. In good work, this upper sheet is carried quite over the roll and about $1\frac{1}{2}$ inches along the flat, as shown at *e*.

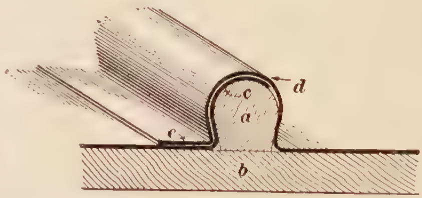


Fig. 57

In the North of England and in Scotland, clips or tingles of lead are not infrequently used instead of rolls, the construction being very similar to that shown in Fig. 46.

114. Drips in Lead Flats.—The maximum allowable length of a lead sheet being 10 feet, drips are required along the slopes of a lead flat at intervals of slightly less than 10 feet ; in the best work they are spaced about 7 feet 6 inches apart. They may be constructed in two ways, as shown in Fig. 58 (*a*) and (*b*).

In (*a*), the sheet on the lower level *a* is bent up and over the step *b*, the edge being let into a rabbet, cut for it in the boarding

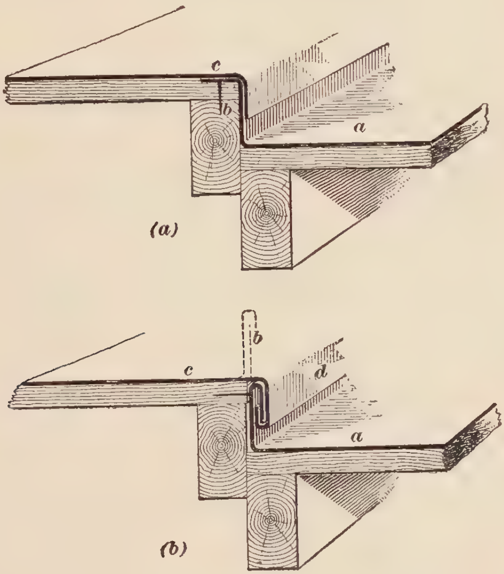


FIG. 58

of the higher level, and nailed securely, as shown, copper tacks $\frac{3}{4}$ inch long being used. The upper sheet *c* is then lapped over it and turned down. To avoid capillary attraction, there should be a space of at least $\frac{3}{4}$ inch between the edge of the upper sheet and the sheet on the lower level.

In (*b*), the method shown in which is not often adopted, the lower sheet *a* is bent so as to extend $1\frac{1}{2}$ inches above the upper level, as indicated by the dotted line *b*. The sheet *c* is bent up

and over the edge of the lower one, and the two sheets are then folded over and downwards, forming a lock *d*, as shown. The minimum depth for a drip is 1½ inches, but a depth of either 2 or 2½ inches is desirable in good work on flats, and even more may be allowed in gutters where a great amount of water collects.

115. Bottle-Nose Drip.—The method of constructing a drip at the junction between the surfaces of a lead flat and a pitched roof is shown in Fig. 59. The flashing *a* on the sloping surface is turned upwards and nailed to the edge of the boarding of the flat, and over this is nailed a wooden nosing *b*. The edges of the lead sheets *d*, *d* are bent round and thus secured to clips *c*, *c* let into a rebate in the edge of the flat roof, the sheets *d*, *d* being then bent over the nosing in the form of a drip. The sloping roof in the illustration is shown to be constructed of shingles, but the construction of the drip will be just the same if the roof is of slates, tiles, or other ordinary roofing material. A drip of this type is called a **bottle-nose drip**, and is sometimes used in ordinary lead flats. Occasionally, the wooden moulding *b*, in Fig. 59, is dispensed with, and the boarding of the flat is carried over beyond the face of the wooden bearer, on which it rests, and rounded off to form a nosing; but this is not so good an arrangement as that shown in the illustration, in which the flashing *a*, by being taken underneath the nosing *b*, is able to be secured in a very thorough manner.

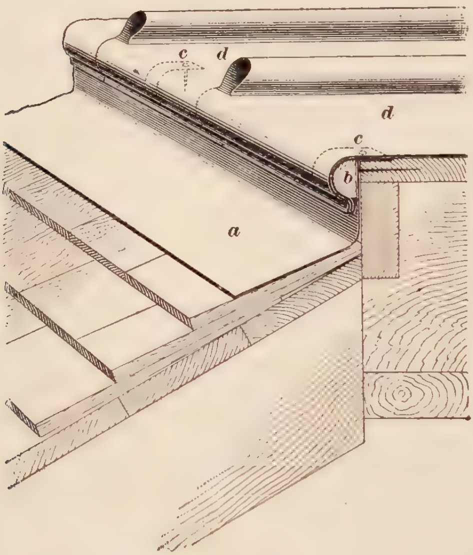


FIG. 59

116. Plumbers' Tools.—The tools used by plumbers for work in connection with lead flats and roofs are shown in Fig. 60; the remaining plumbers' tools employed are described in *House Drainage.* The bossing stick at (*a*) and the dresser at (*b*) are used for working sheet lead into the various forms required, and the bossing mallet at (*c*) and wedge mallet at (*d*), though some-

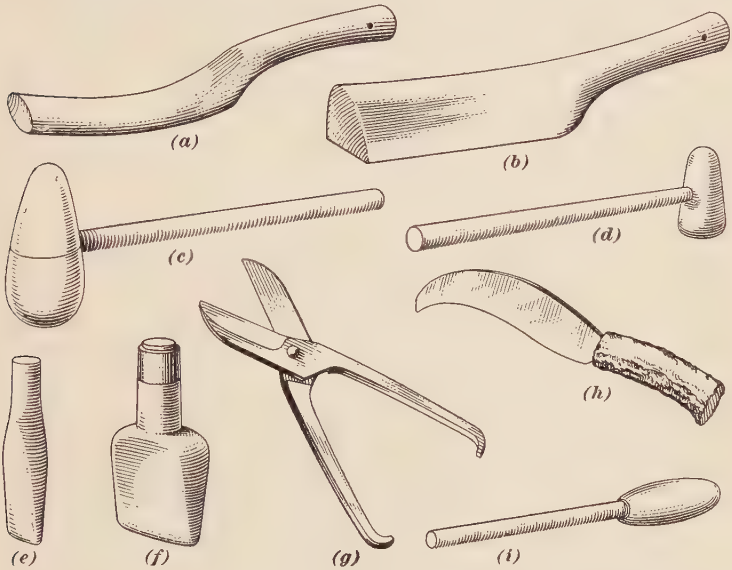


FIG. 60

times required for working the lead direct, are made for the purpose of striking the bossing stick and the dresser. In working the lead into corners, the drift at (*e*) and the chase wedge at (*f*) are used. The tools for cutting sheet lead are the shears at (*g*) and the draw-knife at (*h*). At (*i*) is shown the hand dummy, used for a similar purpose as the bossing stick and dresser, but more particularly in connection with lead pipes.

SHEET-ZINC ROOFING

117. Properties of Zinc.—Zinc, one of the useful metals, is generally extracted from mountain limestone and magnesium limestone in conjunction with galena. The ore is roasted, mixed

with charcoal, and heated in special retorts. The zinc is converted into vapour, condensed, and fused. *Cast zinc* is brittle when cold. Heated to 200°, it is ductile as well as malleable, and may be rolled into sheets which will retain these properties at that temperature; while, if the temperature is allowed to exceed 400°, the zinc will return to its original condition of brittleness. When exposed to the air, at a high temperature, it will burn and be consumed. Zinc is easily acted on by moist air, but a film of oxide is soon formed and this protects the metal from further action. Its expansion under heat being slightly more than lead, it is consequently greater than that of any other common metal.

118. Qualities of Zinc.—Zinc is used to some extent for roofing purposes in the United Kingdom, but is rarely adopted in the United States. Good zinc should be free from iron, and zinc containing more than 1 per cent. of lead should be rejected, the lead making it brittle. Good sheet zinc is uniform in colour, tough, and easily bent without cracking. Inferior zinc is dark in colour and has a blotchy appearance, caused by the presence of other metals. The conjunction of the dissimilar metals may set up galvanic action, which soon destroys the zinc. For this reason zinc should not be secured by, or connected with, iron, copper, or lead. It should not be laid on oak boarding, as the acid in the wood is likely to attack the zinc.

119. Gauge and Sizes of Zinc Sheets.—Zinc is usually supplied in sheets 6, 7, and 8 feet long by 2 feet 8 inches to 3 feet wide, but specially rolled sheets up to 10 feet in length can be obtained. The zinc most frequently specified is that of the Vieille Montagne Company, who have mines in Belgium, Sweden, and Spain, but ordinary London-rolled zinc is of almost equally good quality. Zinc is described by the thickness of the sheets, both the gauges and the weights per square foot being given in Table VII, which is that of the Vieille Montagne Company, the London gauges being approximately the same.

A point of special importance is that the zinc gauge runs in the reverse direction to both the Birmingham wire gauge and the Standard wire gauge, in which gauges the lower the gauge

number the thicker the metal, while in the zinc gauge the lowest gauge number gives the thinnest metal. No. 14 gauge is the

TABLE VII

GAUGE, THICKNESS, AND WEIGHT OF ZINC

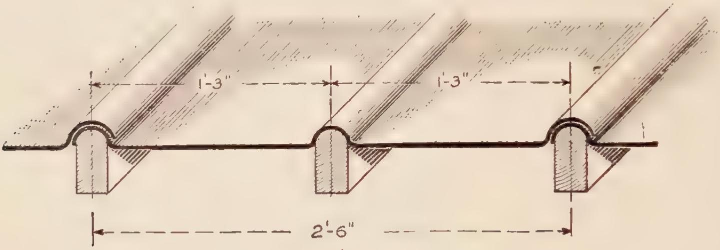
Gauge Number	Thickness Inch	Weight Ounces	Gauge Number	Thickness Inch	Weight Ounces
9	·0165	10·31	14	·0326	18·75
10	·0180	11·44	15	·0364	21·75
11	·0217	13·30	16	·0400	24·75
12	·0254	15·10	17	·0437	27·69
13	·0290	16·94	18	·0478	30·69

thinnest metal that should be used for roofing, and a higher gauge should be adopted, if possible.

120. Method of Laying Zinc.—Zinc is laid in sheets from 7 feet to 8 feet in length and 2 feet 8 inches to 3 feet in width. The distance apart of the rolls is similar to that in the case of lead, but the drips are closer together. The form of the rolls is exactly similar to that adopted for copper. Solder is sometimes used for finishing the stopped ends of zinc rolls, but this is undesirable. The construction and depth of the drips are similar to leadwork. The use of roofing felt over the boarding is very desirable, as if this precaution is not taken, any twisting or curling of the boards will be likely to cause cracks in the zinc along the lines of the joint in the boarding.

121. Laying Italian-Pattern Zinc Sheets.—By adopting sheets rolled in what is termed the **Italian pattern** the use of roof boarding may be dispensed with. The sheets are rolled with corrugations about 1 foot 3 inches apart, there being three corrugations in a sheet, one at each end and one in the centre. The sheets are laid with the joists or rafters fitting into the corrugations and rounded at the top, as shown in Fig. 61 (*a*), there being a side lap of one corrugation. If the thickness of the joists or rafters is more than $1\frac{3}{4}$ inches, this thickness must

be reduced at the top to fit the corrugations, as shown in Fig. 61 (*b*). This form of sheeting may be laid to the minimum pitch of zinc, in which case the joints at right angles to the slope of the roof must be made with drips; but if the pitch is not less than 1 in 15, or 8 inches in 10 feet, drips may be dispensed with



(*a*)

(*b*)

Fig. 61

and the sheets laid merely with an end lap of from 4 to 6 inches. The only danger in this method of laying the sheets is that the water running down the roof may be drawn up between the sheets by capillary attraction, and so find its way into the building.

FLAT ROOFS OF COPPER

122. The use of copper was at one time almost entirely restricted to pitched roofs, but as it is now being realized that it is very little more expensive than lead for roofing, and, if anything, is more durable, even on a flat surface, its adoption for both pitched roofs and flats is becoming more general. Copper flats may be laid merely with welted joints, as the expansion of the material under heat is much less than in the case of lead, but for the best work both rolls and drips are provided.

ASPHALT ROOFING

123. Asphalt.—Rock asphalt consists of rock impregnated with a natural pitch, termed bitumen. The material is obtained both in Europe and America. In Europe, the chief mines are in Switzerland, Germany, France, and Italy, and the stones in which the bitumen is found are usually limestones. In America the circumstances are reversed, and pitch-impregnated sandstones are more common. Compressed-rock asphalt is largely used for road paving, but it is not suitable for roof covering. The asphalt used for roofing is of a mastic character, and consists of a mixture of Trinidad bitumen and rock asphalt. Coal-tar pitch is sometimes used instead of the bitumen, and crushed limestone, sand, or coke breeze instead of the rock asphalt. Bitumen is obtained in large quantities from a lake of this material in Trinidad, and is often, but erroneously, termed Trinidad asphalt.

124. Method of Laying Asphalt.—Asphalt for roofs is laid hot, usually in two layers, having a total thickness of either $\frac{3}{4}$ inch or 1 inch, and forms a very sound and substantial covering. This finish is frequently adopted for concrete roofs, and in such cases it is of great importance that the concrete is finished off to a very smooth surface, for if the surface is uneven the thickness of the asphalt will not be uniform, and there will be a wasteful use of material. Asphalt is sometimes used on wood boarding, but this practice is not to be recommended, as when such a durable and expensive material as asphalt is adopted, it is desirable to lay it on a more substantial basis than ordinary wood boarding. When, for reasons of economy, a light construction of this kind has to be adopted, the covering should preferably consist of metal or of one of the forms of composition sheeting. The flashings against walls, chimney stacks, etc., on an asphalt roof should preferably be also of asphalt, which is usually carried up a little distance against the vertical face and turned into a joint in the brickwork.

125. American Methods of Laying Asphalt.—In America, asphalt is used for the covering of roofs in a more economical and less substantial manner than that customary in the United

Kingdom, and the material is frequently laid on boarding. One method consists in laying felt over the roof boarding, then applying a coat of hot asphalt, and finishing with a covering of gravel. Another method is to lay sheets of felt saturated with asphalt, and finish the surface with sand. A third method is similar to that first mentioned, except that the finishing is done with a coating of Portland cement.

ASBESTOS ROOFING

126. Properties and Use of Asbestos.—Asbestos is a white, grey, or green-grey fibrous mineral. The fibres are sometimes very long, easily separable, and flax like, sometimes compact and capable of a high polish. Asbestos is very soft when reduced to powder, is incombustible, and from white, green, and grey turns to red and black. It is mined in Canada, the United States, and Italy. Asbestos for roofing purposes is usually made in rolls, though in the United States asbestos shingles may now be obtained, and laid in the same manner as wooden shingles.

127. Laying Asbestos Roofing.—This form of roofing is usually laid on ordinary fir boarding, and is suitable both for flat and pitched roofs. Before applying asbestos, the roof surface should be cleaned of all refuse, and care should be taken that the joints of the boards are planed to a level surface and then thoroughly swept.

The roofing should be unrolled, as shown in Fig. 62, care being taken that the material passes over and not under the roll, otherwise the sheets will be laid incorrectly, it being necessary to have the coated side up, to shed the water properly. Commencing at the eaves, the sheets, in the case of flat roofs, should be laid in succession parallel to the eaves, but in the case of pitched roofs they should extend from eaves to ridge. The lap for flat roofs should not be less than 2 inches, but for pitched roofs $1\frac{1}{2}$ inches is sufficient. All edges and laps

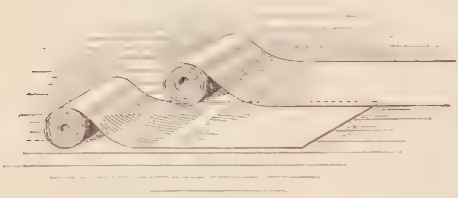


FIG. 62

should be cemented before being nailed down, the nails being spaced 1 inch apart. When the roofing has been nailed, the joints and laps should be cemented a second time, for the purpose of concealing all nail heads and filling up the edges as much as possible. Next, a coating should be applied to the entire surface of the roof, and when thoroughly dry, a second coating, and the surface finished, while fresh, with an even covering of finely ground asbestos powder.

COMPOSITION SHEETING

128. Light Forms of Composition Roof Covering. — During late years the use of special forms of composition sheeting for the covering, both of flat and pitched roofs, has become very general in cases where an economical but reasonably efficient form of roof is desired. There are several patented forms of composition sheeting which have been found to give satisfactory results, and two of the most common are *vulcanite* and *ruberoid*. These may be used both on wood boarding and on concrete, but in important buildings, where the question of expense is immaterial, it is customary to cover a concrete roof with asphalt.

129. Vulcanite.—**Vulcanite** is a bituminous elastic composition which is used in a boiling-hot state, and is applied to a roof in several layers. Each layer is separated from the one immediately above and the one below by sheets of asphalted felt, a layer of which is placed on the boarding or concrete before the vulcanite is laid. Three layers of vulcanite are customary, although, for considerations of economy, sometimes only two layers are applied. The top layer is always covered with a layer of sand, and on this is spread a layer of gravel, which completes the roof. The sand and gravel are provided in order to protect the vulcanite from the heat of the sun and the possible effects of fire from adjoining buildings. An example of a boarded flat covered with vulcanite is shown in Fig. 63, in which a represents the boarding, b, b', and b'' the layers of asphalted felt, c, c', and c'' the layers of vulcanite, d the layer of sand, and e the layer of gravel. At f is shown the customary zinc kerb which must be provided to prevent the gravel from sliding into the gutter. Vulcanite is adaptable for

flat roofs only, the most suitable slope being 1 in 40, or about $3\frac{1}{2}$ inches in 10 feet.

130. Ruberoid.—Ruberoid is a fibrous fabric saturated and coated with a special compound, which, though of a rubber-like character, contains no rubber, and does not in course of time become hard and useless, as is the case with real rubber. It can be adopted for both flat and pitched roofs, but its use on pitched roofs is generally restricted to buildings of only a semi-permanent

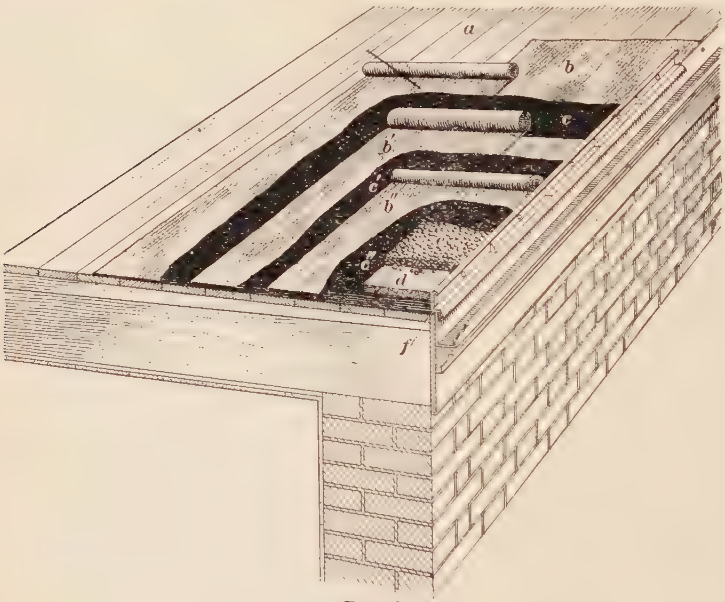


Fig. 63

character. Ruberoid is supplied in rolls 72 feet long and 36 inches wide, and in four different thicknesses, termed $\frac{1}{2}$ ply and 1, 2, and 3 ply, respectively. The usual colour is grey, but it may be obtained, if required, of a green or red colour. The coloured forms of sheeting are, however, made in one thickness only

131. Laying Ruberoid.—Before laying ruberoid, the sheets should be unrolled and the material exposed to the weather for about 14 days, in order to allow it to expand. This is a most important precaution. The material may be laid on wood

boarding or on concrete. In the case of flat roofs, the sheets may be laid either parallel with, or at right angles to, the eaves, but for pitched roofs the sheets must run in the latter direction. The junction of the sheets should not be made exactly at the ridge, but slightly on one side, preferably on the least exposed side, of the roof, as shown at *a* in Fig. 64. The sheets should

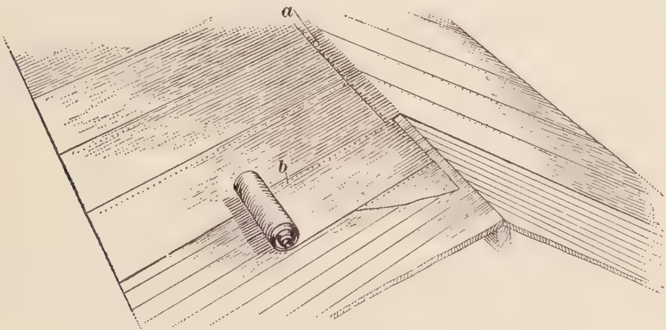


Fig. 64

have an end lap of about 3 inches and a side lap of 2 inches, as shown at *b*. Flat roofs of ruberoid may be laid in one even surface, as no rolls or drips are required. The sheets are nailed with galvanized clout nails, spaced at 2-inch centres, and the joints are made water-tight by coating them with special ruberoid cement, which is laid on to form a neat band, about 2 inches in width, over every joint.

ROOF FINISHINGS

FLASHINGS

132. Cases Where Flashings Are Required.—There are various special methods of rendering a roof water-tight at the places where it abuts against a vertical surface. These consist in the use of lead or zinc, and very occasionally copper, in the form of flashings. A roof may abut against a vertical surface in three different ways, for each of which a different form of flashing is required. It may (*a*) slope down to a vertical surface; (*b*) slope away from a vertical surface; or (*c*) slope, or rake, as it is often termed, along the face of a vertical surface. In

the first case a gutter must be provided at the bottom of the roof slope; in the second, an apron or cover-flashing will be required to cover the junction of the vertical surface of the wall or chimney with the sloping surface of the roof; and in the third case it will be necessary to provide a flashing following the rake of the roof.

133. Forms of Flashing.—The three forms of flashing are illustrated in Fig. 65, which shows the finish of a roof round a chimney stack, *a* being the gutter at the back of the stack, *b* the apron covering the upturned edge of this gutter, *c* the apron or cover flashing in front where the roof slopes down from the stack, and *d* the stepped flashing extending down the slope of the roof. The gutter *a* and the apron flashing *c* should each be about 6 inches longer at both ends than the width of the chimney, as is illustrated by the dotted line. They can then be properly covered by the slates or tiles and water-tight joints be secured. It should be particularly noted that at the corners the flashing which is uppermost is always turned over the one beneath. Thus a portion of the back gutter *a* and the apron *b* is turned over the stepped flashing *d*, while a portion of the stepped flashing *c′* is turned over the apron *c*, the same method being followed on the other side of the chimney.

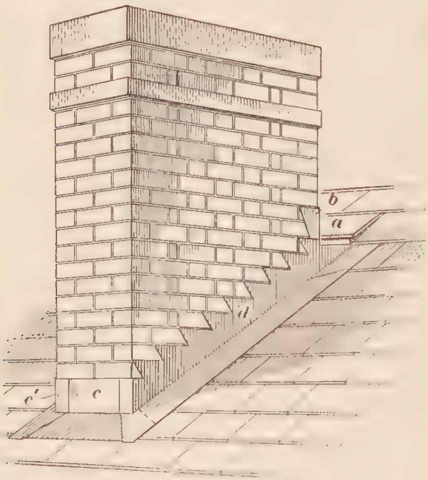


Fig. 65

134. Details of Flashing Construction.—The construction of flashings is illustrated in further detail in Fig. 66 (*a*) and (*b*). A section from front to back of the stack is shown in (*a*), and

a section through the side of the stack cutting the stepped flashing *d* in (*b*). The gutter *a*, which is carried by small bearers fixed to the rafters, is about 9 inches wide, and the apron *b* covers the upturned portion of the gutter *a*. The flashings *c* and *d* extend about 6 inches on the top of the slates, tiles, or other roof covering. The upper edge of a flashing must be turned about 1 inch into a joint in the brickwork and secured by means of lead wedges. Stepped flashings are used only in the case of brickwork; where the vertical face against which a

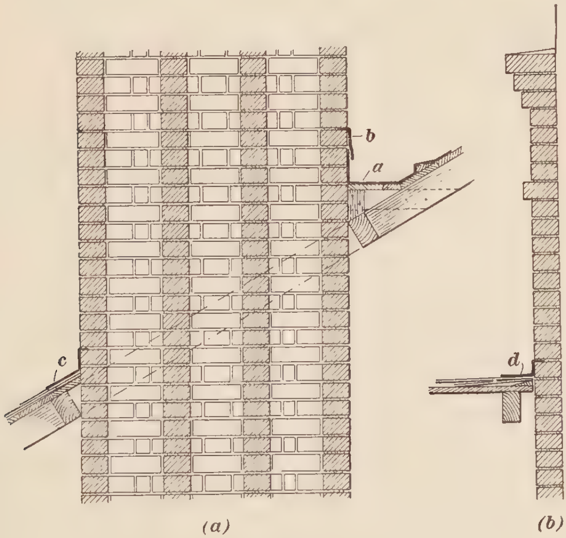


Fig. 66

roof abuts is of stone, it is customary to cut a straight groove in the stonework, parallel with the rake of the roof, for the purpose of receiving an ordinary cover flashing. These methods of construction apply not only to the case of the intersection of a roof by a chimney stack, as shown, but to all cases where a roof abuts against a vertical surface, though in the finish of a roof against a parapet wall, the construction of the gutter demands special treatment on account of the usual long length of the gutter.

135. Use of Soakers.—Stepped flashings, instead of being in one length as shown in Fig. 65, are sometimes made up of separate pieces with their edges overlapping one another, but this method is not general. A very common method in good work, however, is to provide soakers with a narrow stepped cover flashing. Soakers are pieces of lead, zinc, copper, or tin of a length equal to the gauge plus the lap of the roofing material, and of a width of 8 or 9 inches. When used against vertical surfaces, they are bent to a **V**-shaped form, about half the width going under the roof covering and the other half up against the face of the wall or chimney. A soaker is laid at the same time as each slate or tile, and is secured either by being nailed to the boarding or battens, or by being clipped over the top of the slate or tile.

136. Laying Soakers on Slated Roof.—The method of laying soakers on a slated roof is shown in Fig. 67. The highest soaker is shown at *a* and the highest slate at *b*. The soaker and slate immediately lower are shown respectively at *c* and *d*, the latter being only a half slate, in order that the slates may break joint in the usual manner. If the laying of the slates and soakers is proceeded with, the soaker *a* will, of course, be overlapped by another soaker, just in the same manner as it overlaps the soaker *c*; also, the uppermost portion of the slate *b* will be overlapped by two slates to the extent of the lap of the slates. Thus, in the completed roof, the soakers are thoroughly well covered by the slates, and the junction between the soakers and the brickwork is usually covered by a stepped flashing. As the length of a soaker is usually equal to the gauge plus the lap of the roofing material, it is obvious that the soakers, when laid, will have a single lap equal to the ordinary double lap of the slating.

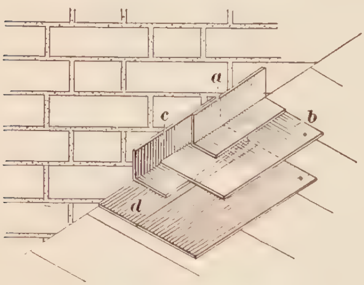


Fig. 67

137. Sloping Secret Gutters.—A type of sloping **secret gutter** is sometimes used under a stepped flashing in the place of soakers.

It is a gutter running up the rake of a roof, as shown at *a* in Fig. 68, there being a tilting fillet *b* running parallel to the sides of the slates. The lead gutter is carried over the tilting fillet and underneath the roof covering, and is covered on its other edge by a stepped flashing *c*. Gutters of this nature are often made very narrow, and the roof covering is carried so far over the tilting fillet that it nearly touches the wall. Although by this means the lead gutter is protected from the effects of the sun, the arrangement is not desirable, as the gutter is liable to be choked by dirt and leaves.

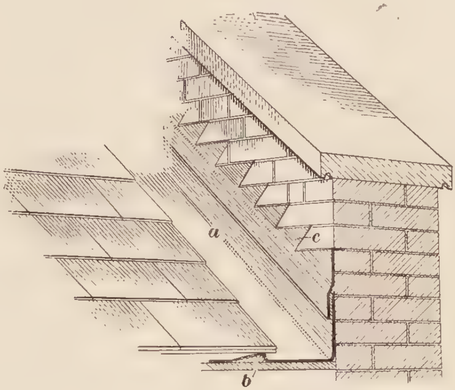


FIG. 68

138. Covering Vertical Faces With Lead.—Comparatively large vertical surfaces, as, for instance, the cheeks of dormer windows, are not infrequently required to be covered with metal as a protection from the weather. If lead is used, it is customary to secure it and prevent it from creeping by the provision of one or more **soldered dots,** or **lead dots** as they are sometimes termed. The process of forming a soldered dot consists in making a hollow about 3 inches in diameter in the boarding, dressing the lead into this hollow, securing it to the boarding, and preferably quite through to the studding at the back by means of a screw, with a washer on the face, and then filling the whole up flush with solder. A section of a soldered dot is given in Fig. 69, the screw and washer being shown at *a*, the lead sheet at *b*, and the solder at *c*. Soldered dots are sometimes objected to because of the tendency for the lead to crack round the dot.

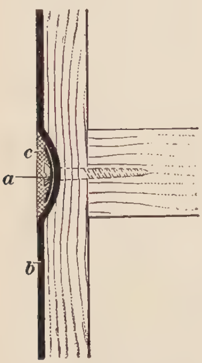


FIG. 69

GUTTERS

EAVES GUTTERS

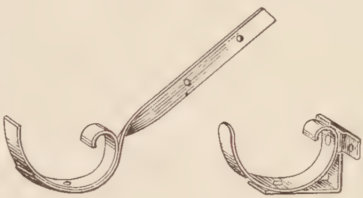
139. Two Principal Types of Gutter.—Gutters must, of course, be provided to all roofs for the purpose of carrying off water. There are two principal types of gutter, namely, those used at the finish of the eaves of a roof, which are generally constructed of cast iron or, in cheap work, of zinc, and those which occur, in the form of parapet gutters, in places where the bottom of a roof is stopped by a wall, or in the form of valley gutters, where two roof slopes are drained into the same gutter. These latter gutters are usually constructed of sheet lead or zinc, or occasionally of copper, and, in the United States, frequently of tin.

140. Forms of Eaves Gutter.—Eaves gutters may be either of half-round section, as shown in Fig. 70 (*a*), or of moulded form, as shown in Fig. 70 (*b*) and (*c*). These illustrations must, however, be taken merely as representing types, for half-round gutters may be obtained of sections varying from a comparatively shallow form to what are termed deep half-round gutters, in which the depth is increased by raising the sides a distance of several inches, while moulded gutters of almost innumerable shapes may be obtained. The form shown in (*b*), which, from the shape of the profile, is termed an ogee gutter, is largely used in everyday work. Half-round gutters may be obtained in widths of 3, $3\frac{1}{2}$, 4, 5, and 6 inches, the $3\frac{1}{2}$-inch and 4-inch sizes being those in common use, and moulded gutters are made from 3 inches to about 12 inches in width and from 2 inches to 6 inches in depth. The thickness of the metal in cast-iron gutters is either $\frac{3}{16}$ inch or $\frac{1}{4}$ inch, and zinc gutters are of No. 14 or No. 16 gauge. Gutters are obtained in standard lengths of 6 feet. In work of the very best class, eaves gutters of heavy cast lead, with ornamental rain-water pipe heads of the same material, are often used.

(*a*) (*b*) (*c*)

Fig. 70

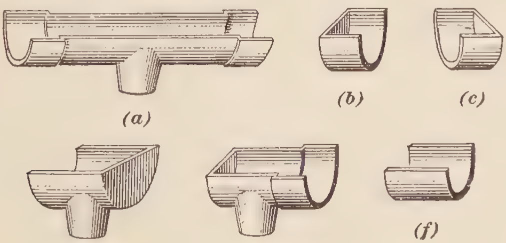
141. Fixing Eaves Gutters.—Eaves gutters should be laid to a fall of not less than 1 inch in 10 feet, and down pipes should, if possible, be provided at distances not exceeding 30 feet. The size of a gutter is, of course, governed by the area of the roof space which it is required to serve. The width of the nozzles connecting with the down pipes should be in reasonable proportion to the width of the gutter, and the nozzles should not in ordinary cases be less than 3 inches in internal diameter. Half-round gutters are carried on wrought-iron brackets spaced 3 feet apart, a form of bracket for use when there is no fascia, and the brackets are secured to the feet of the rafters, being shown in Fig. 71 (*a*), and a form of bracket for use when a fascia is provided being shown in Fig. 71 (*b*). Moulded gutters are usually fixed by being screwed direct to the fascia, or, in the case of a coke-breeze concrete roof, where there is no fascia, by being nailed to the concrete.



(*a*) (*b*)

FIG. 71

142. Lengths of Guttering.—Gutters are constructed so that every 6 feet of length has a half socket or faucet at one end, into which the spigot end of the next length of gutter will fit,



(*a*) (*b*) (*c*) (*d*) (*e*) (*f*)

FIG. 72

the junction of the two lengths being secured by a bolt, and rendered water-tight by means of red lead and tow. The lengths of guttering are laid so that the faucet ends are higher than the

spigot ends. Special junction pieces are made for right angles and obtuse angles, and also special forms for nozzles and stopped ends. Examples of the latter, as applicable to half-round guttering, are shown in Fig. 72, a nozzle piece being shown at (*a*), a spigot-stop end at (*b*), and a faucet-stop end at (*c*). A combination of nozzle and stop end, as applied to the spigot end of a length, is shown at (*d*). This is termed a spigot-drop end. A faucet-drop end is shown at (*e*), and a clip which is used for the purpose of uniting lengths of guttering when two spigot ends come together is shown at (*f*). Both spigot-stop ends and clips are placed on the under side of gutters, but a faucet-stop end is put inside, bolts being used in all cases to secure these pieces to the lengths of guttering. Special forms similar to those shown are supplied in the case of moulded gutters.

It is most important in fixing eaves gutters to see that there is no sagging in the lengths of guttering, or otherwise, when there is heavy rain, the gutters will be liable to overflow at the points where the sagging occurs.

PARAPET AND VALLEY GUTTERS

143. Parapet Gutters.--The construction of parapet gutters is similar in principle to that of the small gutter, shown in section in Fig. 74, at the back of a chimney stack. But as, in ordinary cases, the length of a parapet gutter is very considerable, it is necessary to provide drips, at intervals of about 10 feet, constructed in an exactly similar manner to those used in the case of flat roofs. The drips cannot satisfactorily be made of a less depth than 2 inches. A depth of 3 inches is desirable, and the least allowable fall in gutters of this kind is $1\frac{1}{2}$ inches in 10 feet; thus, in a long length of gutter, the level at the upper or top end of the gutter may easily be a foot or more above that at the bottom or lower end. In consequence of this, a parapet gutter which is bounded on one side by a sloping roof is always wider at the upper end than at the lower end, for, as the level of the gutter rises, the horizontal distance across from the wall to the sloping roof naturally increases.

144. Width of Parapet Gutters.—An illustration of a parapet gutter is given in Fig. 73, in which *a* is the lead or other material forming the gutter, *b* the flashing against the wall, protecting the upturned edge of the gutter, and *c*, *c* the drips in the gutter which occur at intervals of about 10 feet. Gutters of this kind are always set out from the bottom, where the width is at its minimum, which is usually about 9 inches. It will be seen from Fig. 73 that as the level of the gutter rises its width increases very considerably. The lead or other metal of parapet gutters is usually carried on fir boarding *a*, 1 inch in thickness, which rests upon gutter bearers *b* placed at the feet of every rafter, as shown in Fig. 74. At *c* is shown the metal covering to the boarding taken up under the slates *d* and over the tilting fillet *e*. This covering is turned up against the wall and is covered with the flashing *f*.

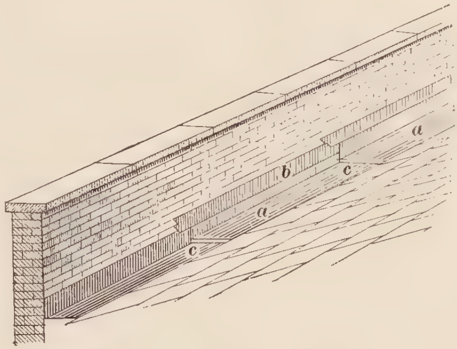


Fig. 73

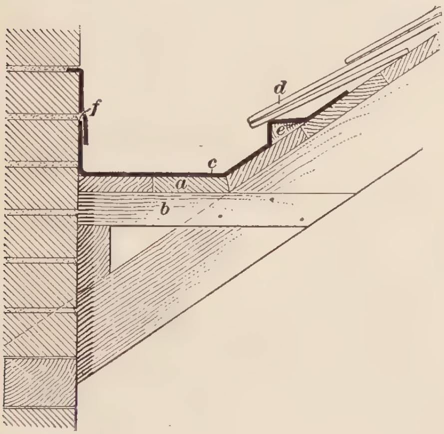


Fig. 74

145. Cesspools.—The water from a parapet gutter may be conveyed through an opening in the wall directly into an ordinary rain-water head, but in good work it is the custom to form a cesspool at the lowest point of the gutter. This consists in effect of a wooden box lined with lead, with a hole in the

bottom for the reception of the socket pipe, which connects the cesspool with the rain-water head, the depth of the cesspool being from 6 to 9 inches. The construction of a cesspool is shown in longitudinal section in Fig. 75, in which the $1\frac{1}{4}$-inch boarding forming the boxing is shown at *a*, the finish of the leadwork of the parapet gutter at *b*, the outlet for the socket pipe at *c*, and the lead lining of the cesspool at *d*. The lining is usually cut out of a single piece of lead and the edges soldered together, and the junction of the socket pipe with the cesspool should also be soldered. This is an exception to the general rule that solder should not be used in leadwork for roofs. As a precaution in case the outlet of the cesspool should become stopped up, it is well to provide an overflow pipe near the top of the cesspool, as shown by dotted lines at *e* in Fig. 75.

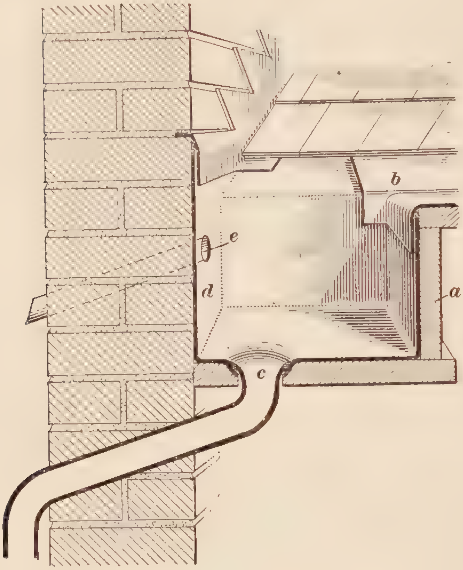


Fig. 75

146. Valley Gutters. The gutters formed in a valley between two roofs are usually of the form shown in Fig. 76, a cross-bearer *a* being spiked to each pair of rafters at their junction, and the ordinary boarding *b* of the roof being carried

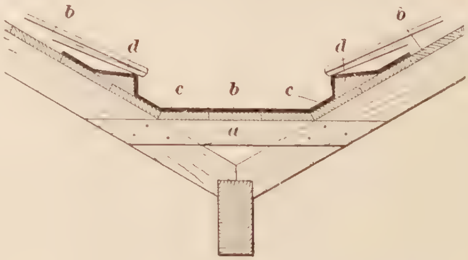


Fig. 76

along on the top of the cross-bearers to form the base of the gutter. The cross-bearers are not all fixed at one level, but are adjusted according to the required fall of the gutter. The lead or other metal of the gutter *c* is taken up over the tilting fillet *d* and carried a few inches under the roof covering. Gutters of this type vary in width at different levels to a greater extent than parapet gutters, as they are finished, not against one, but against two sloping surfaces.

147. Box Gutters.—When the rafters *a*, *a*, Fig. 77, of the two roofs, instead of resting on a single plate as shown in Fig. 76, are carried by separate pole plates *b*, *b*, Fig. 77, notched or cogged to the principal rafters *c*, *c*, it is customary to form a **box gutter**, as shown in Fig. 77. Such a gutter has parallel sides, and therefore is different from the ordinary form of valley gutter, the width of which varies according to the level. The

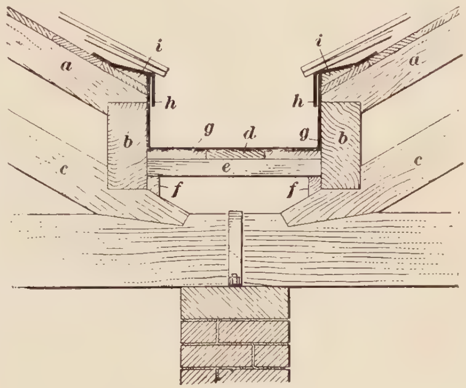


Fig. 77

bottom of a box gutter is of boarding *d*, carried on gutter bearers *e*, spaced about 12 inches apart and fixed on blocking pieces *f*, *f* spiked to the pole plates, as shown. Both the sides and the bottom of the gutter are then covered by a sheet of lead or other metal *g*, and the turned-up edges of the lead are protected by apron flashings *h*, *h* running under the roofing material and over the tilting fillets *i*, *i*.

148. Snow Boards.—In order that snow, when thawing, may be able to drain away freely on the under side, where, on account of the warmth of the building beneath, it usually commences to melt, it is customary in good work to lay **snow boards** along the top of parapet and valley gutters. Snow boards are constructed of strips of wood, as shown at *a*, Fig. 78, which run

longitudinally with the gutter, and are carried by cross-bearers *b* of a width suitable to the gutter in which they are to be placed, and are spaced from 2 to 3 feet apart. The cross-bearers are hollowed out on the under side, as shown at *c*, so as not to impede the draining away of the melted snow.

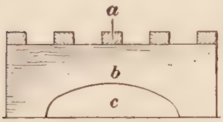


FIG. 78

SHEET METAL ON CORNICES

149. Protection of Cornices and Mouldings.—It is necessary to protect the tops of cornices and large projecting mouldings by covering them with metal. If the top of the cornice or moulding is sloped away from the face of the building, little difficulty is experienced in arranging the covering, which is usually of lead, for it can be laid in lengths of about 7 feet with welted joints. If, however, the top of the cornice slopes toward the building and a gutter is provided adjoining the face of the building, as shown in Fig. 79, where *a* is the cornice and *b* the sheet-metal covering to same, there is much more difficulty, for welted joints, when taken across the gutter, could not be expected to be water-tight. In such a case, it will be necessary to form the joints by means of either soldering or burning, the latter method consisting in cutting a dovetailed groove in the stone, turning into the groove the two ends of the sheets which are required to be joined, and then running molten lead into the groove. To reduce the number of joints to a minimum, very long pieces of metal are often used.

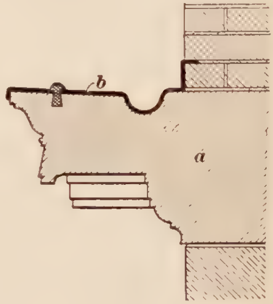


FIG. 79

150. Securing Metal Covering.—The metal covering is usually held down near the front either by soldered dots similar in form to those which have been described, or by cast-lead dots, the latter being the better arrangement, as the top of the dot forms a weathering. One of these cast-lead dots is shown in section in Fig. 80. A dovetailed circular hole *a* is first made in the stone,

then the lead is laid and a small hole formed in it, as shown at b. Molten lead is then poured into the hole, and the top of the dot c is formed by means of a special mould with a hole in the top, through which the lead is poured. Copper is sometimes used for covering cornices, its advantage being that it can be satisfactorily fixed with welted joints, so no dots are required.

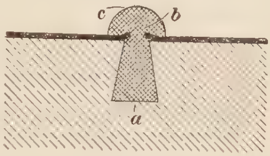


FIG. 80

151. Sheet-Metal Cornices and Mouldings.—In the United States it is a very common practice to construct cornices, string-courses, and similarly moulded portions of a building in sheet metal, either galvanized iron or copper. Galvanized iron is usually painted on completion, and copper, when used, is often stamped into ornamental patterns. These sheet-metal mouldings are sometimes fixed on a wooden framework, although an iron framing is usually adopted.

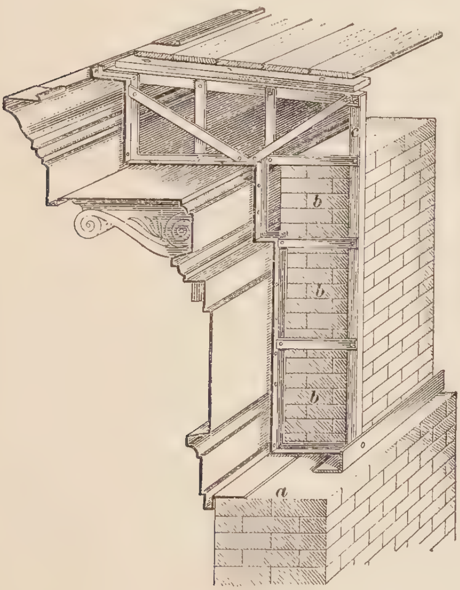


FIG. 81

An example of a sheet-metal cornice fixed to an iron framing is shown in Fig. 81. The customary method of construction is to stop the brickwork at the level of the base of the cornice, as shown at a, and then to hoist up sections of the cornice, about 14 feet in length and fully attached to the iron frames, which are constructed of angle irons and are spaced from 2 to 4 feet apart. The section of cornice is then held temporarily in position until

the brickwork *b* to counterbalance it has been filled in and the mortar of the joints has properly set. If there is any danger of the cornice being too heavy for the counterweight of brickwork, the legs *c* of the frames should be tied separately to some beam or other rigid part of the building.

152. Joints in Sheet-Metal Mouldings.—The vertical joints in sheet-metal mouldings are usually made by means of special rivets, the sheets being either lapped one over the other, or finished by a butt joint with a vertical strip of metal riveted at the back to both sheets throughout the length of the joint. Horizontal joints are made in a variety of ways, but the following methods illustrate good practice when the joints must be made on the job.

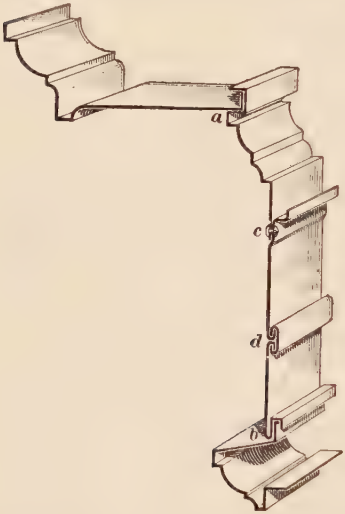


FIG. 82

Interlocking joints, termed *cup joints*, necessary only in large cornices, are shown at *a* and *b*, Fig. 82. The position of the metal shows how the joints appear when the cornice is being fitted up. After it is lined up in place, with its vertical joints made, the edges are bent over twice, thereby locking the seams.

153. Joints on Flat Surfaces.—When a joint must be made on a flat surface, such as on a wide frieze, either of the methods shown at *c* or *d* may be employed. The joint at *c* is lapped and riveted, a stiffener being bent at the back to keep the joint straight. This is the stronger seam of the two. It is preferable to that shown at *d* in places where rain will wash over it. When it is desired to form a very close horizontal joint, the *clinch seam* at *d* may be used. The edges of the sheets are bent over and butted together as shown. A cap is then slipped over them and when the work is lined up, the seam is closed by flattening down the cap, thus drawing the sheets together.

A SERIES

OF

QUESTIONS AND EXAMPLES

RELATING TO THE SUBJECTS

TREATED OF IN THIS VOLUME.

The following Examination Questions are divided into sections corresponding to the text, so that each section has a head-line which is the same as that of the section to which the questions refer.

No attempt should be made to answer the questions or to solve the examples until the corresponding part of the text has been carefully studied.

BRICKWORK

(PART 1)

EXAMINATION QUESTIONS

(1) Describe the various kinds of clay from which bricks are made.

(2) What is tuck pointing?

(3) How are bricks made by the stiff-clay process?

(4) What thickness of mortar joints should be used in common brickwork?

(5) What is herring-bone bond?

(6) Describe and sketch five different tools used by a bricklayer or his labourer.

(7) Describe and sketch the following: Cant brick, bull-nosed brick, queen closer, half bat.

(8) What is Flemish bond?

(9) Describe the methods of striking a mortar joint, and give the reasons for so doing.

(10) Describe one method of bonding hollow walls.

(11) What is a frog?

(12) What is the spandril of an arch?

(13) What is the intrados of an arch?

(14) What is a relieving arch, and why is it so called?

(15) Explain and show by sketches why the joints of arches made with common bricks are wedge-shaped.

(16) Is it better to use rubbed or moulded bricks in arch construction, and why?

(17) What is garden-wall bond?

(18) What are pressed bricks, and for what are they used?

(19) What is English bond?

(20) Name the classifications of bricks according to manufacture.

BRICKWORK

(PART 2)

EXAMINATION QUESTIONS

(1) What is a party wall?

(2) Illustrate two alternate courses of the bonding of a brick pier $3\frac{1}{2}$ bricks square.

(3) Why are curved flues preferable to straight ones?

(4) What can be said about the practice of building timber into walls of brick or stone?

(5) What kind of bricks are used for nogging and why?

(6) A dwelling under the model by-laws is to be 58 feet high; how thick must the brick walls be?

(7) What are the customary sizes of flues (*a*) for ordinary fireplaces, and (*b*) for kitchen ranges?

(8) What should be the relation between the thickness of an outside wall of a building and the thickness of a party wall?

(9) What is the advantage of a hollow brick wall?

(10) Explain the disadvantages of putting a window directly under a pier in a wall.

(11) What is gauged brickwork?

(12) When is an arch bar required in connection with a fireplace opening in a chimney breast?

(13) What is the jointing material for gauged brickwork?

(14) Give an example of a moulded brick string-course.

(15) Illustrate by a sketch section the arrangement of a fire-on-the-hearth stove.

(16) Give the composition of two solutions for waterproofing brickwork.

(17) Give a sketch and description of the arrangement of brick flues for the setting of a kitchen range.

(18) What is the meaning of efflorescence in brickwork, and to what is it to be attributed?

(19) Explain by a sketch section the arrangement of a concrete lintel over a window head in a hollow brick wall.

(20) In the upper floors of a building, how are the hearths in front of fireplace openings supported?

TERRA-COTTA, FAIENCE, AND TILING

EXAMINATION QUESTIONS

(1) With what material are hollow terra-cotta blocks filled before being built into a wall?

(2) Name the two general classes of architectural faience.

(3) What is meant by a clay-sized drawing?

(4) For what reason is sand, or ground brick, added to terra-cotta clay before burning?

(5) What are the principal advantages of terra-cotta for building construction?

(6) Why should the size of bricks for the backing in a wall, behind terra-cotta, be ascertained before commencing the full-size drawings?

(7) How is the material for the manufacture of terra-cotta prepared?

(8) Describe the dust process for manufacturing faience tiles.

(9) Illustrate a method of anchoring down a terra-cotta cornice in a brick wall.

(10) Why should not terra-cotta be trimmed to fit its intended situation when it is delivered at the site of a building?

BUILDING STONES

EXAMINATION QUESTIONS

(1) Distinguish between the various groups into which limestone may be subdivided, and give three examples of each sort.

(2) Give the names and a brief description of three hand tools used in bringing stonework to a smooth face.

(3) What points should be specially noted in selecting stone, and why?

(4) Describe four methods of finishing the face of stone.

(5) What is a margin? Give two reasons for using it.

(6) What are the chief causes of decay in building stone?

(7) What stone would you suggest for use in the following positions, and why? (*a*) River embankment (granite not available); (*b*) elevations for a building in a manufacturing town; (*c*) passages and steps in a warehouse or factory; (*d*) passages and steps in a hotel or club; (*e*) column, heavily loaded, outside of building; (*f*) column, heavily loaded, inside of building.

(8) What are the chief characteristics of slate, and for what is it principally used?

(9) Give two reasons why granite should be worked at the quarry.

(10) Mention two varieties of limestone that are sufficiently hard to take a polish.

(11) What is meant by (*a*) An igneous rock, (*b*) a sedimentary rock, (*c*) a metamorphic rock?

(12) Describe and give sketch of (*a*) a crandall, (*b*) a dummy.

(13) What is meant by bush-hammered work ?

(14) What is (*a*) gneiss, (*b*) trap ?

(15) What is stereotomy ?

(16) What are the principal uses of sandstones ?

(17) Describe the properties and uses of granite, and name three varieties.

(18) What is the essential difference between marble and serpentine ?

(19) What are the chief constituents of building stones ?

(20) What points should be considered when looking for a durable building stone ?

MASONRY

(PART 1)

EXAMINATION QUESTIONS

(1) Sketch the jamb of a window opening and name the parts on it.

(2) What is: (*a*) rubble work; (*b*) block in course; (*c*) ashlar?

(3) What is meant by the terms: (*a*) sunk; (*b*) circular; (*c*) circular circular sunk? (*d*) moulded circular? Give a sketch of each.

(4) What is a lintel? Give a sketch of one.

(5) What is a bondstone, and why is its use advisable?

(6) What is: (*a*) a blocking course; (*b*) an entablature?

(7) Draw two forms of weathered cornices and indicate on each the position of the following terms: (*a*) weathering; (*b*) throating; (*c*) drip.

(8) Describe the usual methods of using flints to face a wall.

(9) Make a sketch of a column with entablature and balustrade over, and name the parts.

(10) What is a pediment? Give a sketch of one.

MASONRY

(PART 2)

EXAMINATION QUESTIONS

(1) Sketch a semicircular stone arch and indicate the position of the following: intrados, extrados, crown, haunch, key, radius, rise, span, springing line, voussoir.

(2) Sketch the method of setting out joints in a true elliptical arch.

(3) Sketch and describe three ways of finishing the soffit of stone steps.

(4) Sketch the following and state the uses of each: cramp, dowel, lead plug, rag bolt.

(5) Sketch the method of setting out joints for a four-centred arch.

(6) What is: (*a*) a joggled joint? (*b*) a tabled joint?

(7) Sketch three methods of jointing stone steps.

(8) Sketch the section through a stair formed with stone slabs.

(9) Describe any well-known method of preserving stonework.

(10) What is a rampant arch? Sketch an example.

CARPENTRY

(PART 1)

EXAMINATION QUESTIONS

(1) What woods are best suited for flooring?

(2) What are cup shakes?

(3) Give some particulars of pitch pine.

(4) What woods are best suited for heavy framework?

(5) Name some conditions affecting the quality of timber.

(6) What are heart shakes?

(7) What is meant by wet rot?

(8) State the relative advantages and disadvantages of natural and artificial seasoning.

(9) What are the causes of dry rot?

(10) What is meant by a hardwood?

(11) What are the uses of Baltic pine?

(12) What is an exogenous tree?

(13) What is the best method of preserving timber to be set in the ground?

(14) What is the difference between heart wood and sap wood?

(15) What is meant by annual rings?

(16) What is a balk?

(17) What is a plank?

(18) What is the object of seasoning timber?

(19) What is meant by quarter sawn?

(20) What is a rind gall?

CARPENTRY

(PART 2)

EXAMINATION QUESTIONS

(1) How is the work of a carpenter distinguished from that of a joiner?

(2) Where are tusk tenons used?

(3) Name some of the cutting tools used by a carpenter, and state, briefly, the use of each.

(4) When should trussed partitions be used?

(5) When two thicknesses of flooring are required, how is the rough flooring generally laid?

(6) (*a*) How are joints classified? (*b*) Sketch two joints in each class.

(7) Describe the different classes of wooden floors.

(8) For what are false jambs used?

(9) (*a*) What is a wall plate? (*b*) Sketch three methods of fixing one.

(10) What is a mortise-and-tenon joint?

(11) What are the uses of dovetail halving?

(12) When is scarfing used?

(13) When floors are to be frequently washed, how may they be laid to prevent water from working through?

(14) Describe the use of plaster grounds.

(15) (*a*) Describe methods of strutting floors. (*b*) Sketch one example.

(16) What is cross-furring?

(17) How is the tongue placed in flooring so as to give more wearing surface and prevent curling?

(18) Describe floor "deafening."

(19) (*a*) What is a trimming joist? (*b*) How is it secured?

(20) When a partition comes between two joists of a floor above, how should it be secured?

CARPENTRY

(PART 3)

EXAMINATION QUESTIONS

(1) What is a valley?

(2) What is meant by the pitch of a roof?

(3) What are windows projecting from a roof called?

(4) What is: (*a*) A kingpost roof truss? (*b*) a queenpost roof truss?

(5) Sketch the joint between the foot of a kingpost and the tie-beam.

(6) What is: (*a*) A couple roof? (*b*) a collar-beam roof? Sketch an example of each.

(7) What is a Mansard roof?

(8) Sketch a plan of a roof and mark on it the following parts: (*a*) Hip; (*b*) ridge; (*c*) valley; (*d*) eaves.

(9) How are roof hips, valleys, etc., made water-tight?

(10) Sketch a double-pitch roof.

(11) What is one of the most important points in spire construction?

(12) (*a*) What is a standing gutter? (*b*) Sketch a section through one.

(13) Sketch, in outline, the elevation of a kingpost roof truss and mark on it the following members: (*a*) Kingpost; (*b*) tie-beam; (*c*) principal rafter; (*d*) common rafter; (*e*) strut; (*f*) ridge; (*g*) purlin.

(14) Sketch a lean-to roof.

(15) How is the foot of the principal rafter secured to the tie-beam in a kingpost roof truss?

(16) In order to secure a good drip, how far beyond the wall plate should the eaves extend?

(17) Why are eyebrow windows used?

(18) What is a pole plate?

(19) What is an ogee roof?

(20) How is the pitch of a roof designated?

CARPENTRY

(PART 4)

EXAMINATION QUESTIONS

(1) What is half-timber work?

(2) How are the joints of veranda flooring rendered water-tight?

(3) On what should the base of a veranda post be set to prevent rotting at the junction with the floor?

(4) How does a trimmer-arch centre differ from an ordinary centre?

(5) What are the intersecting lines at the crossing of two arched ceilings called?

(6) How long should half-timber work stand before the plastering of the panels is begun?

(7) Of what woods can a flagstaff be constructed?

(8) What is a pendentive?

(9) How may the horizontal beam line and the angularity at the wall connections of a bridgeway be relieved?

(10) What should be the proportion of the diameter of a flagstaff in relation to its height?

(11) Why is a mansard or gambrel form of roof preferable for a hay barn?

(12) What is chamfering?

(13) When are wooden centres necessary in brick or stone walls?

(14) What is a dome?

(15) What is a groined ceiling?

(16) What are plaster grounds?

(17) What is weather boarding?

(18) Sketch a section through the corner of a building in imitation half-timber work.

(19) What is siding?

(20) What particular considerations should be studied in connection with the design of a veranda?

ROOFING

EXAMINATION QUESTIONS

(1) What are the minimum roof slopes for (*a*) slate, (*b*) pan tiles, (*c*) lead, (*d*) corrugated iron, (*e*) thatch?

(2) State the two different methods of nailing slates. Which is the better, and why?

(3) Give a sketch of a lead flat, showing particularly the method of furring for falls.

(4) (*a*) What special treatment must be adopted in laying the eaves of a slate roof? (*b*) Is this treatment also applicable to plain tile, pan tile, and shingle roofs?

(5) What are the advantages of copper for roofing purposes, and how does this material compare with lead?

(6) Explain the terms lap and gauge, as used in roofing, and state what relation the lap, gauge, and length of a tile have to each other in a roof covered with plain tiles.

(7) Describe the method of thatching a roof.

(8) Describe fully the differences in the methods of laying plain tiles and pan tiles.

(9) Give sketches of wooden rolls for (*a*) lead and (*b*) zinc, and in each case show the method of finishing the material round the roll.

(10) Describe and illustrate by sketches the method of arranging the flashings, etc., round a chimney stack which intersects a roof

(11) Explain why the higher part of a parapet or valley gutter is wider than the lower part.

(12) What lap should be given to corrugated-iron sheets at the ends and at the sides, and why should the bolts or screws connecting the sheets always be inserted at the top of the corrugations?

(13) Describe the several methods of preparing a roof for slating.

(14) Give a careful sketch showing in elevation, with part of the slates removed, the method of laying centre-nailed Countess slating having a 3-inch lap.

(15) Give a sketch of a sheet-metal cornice, and show the method of fixing it to the wall.

(16) What are the tools used by (*a*) a slater and (*b*) a plumber in roofing work, and for what is each particular tool used?

(17) What weight of lead, in pounds per square foot, should be used for (*a*) flashings, (*b*) flats, (*c*) gutters, and (*d*) soakers?

(18) Give sketches illustrating a common method of finishing a hip in a roof covered with (*a*) slates, (*b*) tiles, and (*c*) shingles.

(19) Illustrate by a section the construction of a drip as used on a lead flat or gutter, and state for what purpose drips are provided.

(20) Explain in full detail the method of replacing a broken slate in a roof without disturbing the rest of the slating.

ANSWERS

TO THE

QUESTIONS AND EXAMPLES

INCLUDED IN THE

EXAMINATION QUESTIONS

Each Key, or set of Answers, has the same section number as the corresponding set of Examination Questions. All references are to the portion of the text that bears the same section number as the Key in which the references occur, unless the title of some other part of the text is mentioned.

To be of the greatest value, the Key should be consulted sparingly, much in the same manner as a pupil would go to a teacher for assistance in solving a problem he is unable to master unaided. The Key should not be referred to except as a last resource, when the student has failed, after using every reasonable effort, to solve the example or answer the question. If used in this way, the Key will be a help and a source of encouragement in studying the various subjects comprising the Course.

BRICKWORK
(PART 1)

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(1) See Art. **2.**
(2) See Art. **69.**
(3) See Art. **11.**
(4) See Art. **39.**
(5) See Art. **59.**
(6) See Arts. **34** and **35.**
(7) See Arts. **26** and **48.**
(8) See Art. **56.**
(9) See Art. **67.**
(10) See Arts. **62** to **64.**
(11) See Art. **6.**
(12) See Art. **71.**
(13) See Art. **71.**
(14) See Art. **81.**
(15) See Art. **73.**
(16) See Art. **77.**
(17) See Art. **57.**
(18) See Art. **24.**
(19) See Art. **54.**
(20) See Art. **4.**

BRICKWORK

(PART 2)

(1) See Art. **6.**

(2) See Art. **13.**

(3) See Art. **18.**

(4) See Art. **15.**

(5) See Art. **14.**

(6) See Art. **2.**

(7) See Art. **18.**

(8) See Art. **6.**

(9) See Art. **5.**

(10) See Art. **11.**

(11) See Art. **44.**

(12) See Art. **21.**

(13) See Art. **44.**

(14) See Arts. **50** to **53.**

(15) See Art. **33.**

(16) See Art. **63.**

(17) See Art. **35.**

(18) See Art. **59.**

(19) See Art. **12.**

(20) See Art. **21.**

TERRA-COTTA, FAIENCE, AND TILING

(1) See Art. **12.**
(2) See Art. **18.**
(3) See Art. **5.**
(4) See Art. **4.**
(5) See Art. **1.**
(6) See Art. **9.**
(7) See Art. **4.**
(8) See Art. **21.**
(9) See Arts. **15** and **16.**
(10) See Art. **6.**

BUILDING STONES

(1) See Arts. **20** and **22.**

(2) See Art. **56.**

(3) See Art. **33.**

(4) See Arts. **63** to **78.**

(5) See Art. **64.**

(6) See Arts. **39** to **44.**

(7) See Arts. **12, 22, 25,** and **30.**

(8) See Art. **31.**

(9) See Art. **11.**

(10) See Art. **22** and Table I.

(11) See Art. **3.**

(12) See Art. **55** and Fig. **1.**

(13) See Art. **74.**

(14) See Arts. **14** and **15.**

(15) See Art. **62.**

(16) See Art. **27.**

(17) See Arts. **9** to **11.**

(18) See Arts. **23** and **26.**

(19) See Art. **7.**

(20) See Art. **38.**

MASONRY

(PART 1)

(1) See Art. **7.**

(2) (*a*) See Art. **41.**
(*b*) See Art. **50.**
(*c*) See Art. **51.**

(3) See Art. **32.**

(4) See Art. **8.**

(5) See Art. **2.**

(6) (*a*) See Art. **28.**
(*b*) See Art. **27.**

(7) See Art. **21.**

(8) See Art. **49.**

(9) See Arts. **26** and **27,** and Fig. 20.

(10) See Art. **29.**

MASONRY

(PART 2)

(1) See Art. **3.**

(2) See Art. **19.**

(3) See Art. **32.**

(4) See Arts. **38** to **40.**

(5) See Art. **20.**

(6) See Art. **41.**

(7) See Art. **32.**

(8) See Art. **33** and Fig. 33.

(9) See Arts. **47** and **48.**

(10) See Art. **22.**

CARPENTRY

(PART 1)

(1) See Art. **73.**
(2) See Art. **15.**
(3) See Art. **41.**
(4) See Art. **73.**
(5) See Art. **10.**
(6) See Art. **16.**
(7) See Art. **34.**
(8) See Arts. **25** and **27.**
(9) See Art. **33.**
(10) See Art. **36.**
(11) See Arts. **38** and **73.**
(12) See Art. **2.**
(13) See Art. **35.**
(14) See Art. **4.**
(15) See Art. **5.**
(16) See Art. **23.**
(17) See Art. **23.**
(18) See Art. **24.**
(19) See Arts. **21** and **22.**
(20) See Art. **17.**

CARPENTRY

(PART 2)

(1) See Art. **2.**

(2) See Art. **35.**

(3) See Arts. **7** and **8.**

(4) See Art. **70.**

(5) See Arts. **58** and **59.**

(6) (*a*) See Art. **12.**
(*b*) See Arts. **13** to **39.**

(7) See Art. **40.**

(8) See Art. **73.**

(9) (*a*) and (*b*) See Art. **49.**

(10) See Art. **28.**

(11) See Art. **27.**

(12) See Art. **15.**

(13) See Art. **59.**

(14) See Arts. **67** and **68.**

(15) (*a*) and (*b*) See Art. **51.**

(16) See Art. **69.**

(17) See Art. **55.**

(18) See Art. **53.**

(19) (*a*) and (*b*) See Art. **52.**

(20) See Art. **64.**

CARPENTRY

(PART 3)

(1) See Art. **4.**

(2) See Art. **1.**

(3) See Art. **40.**

(4) (*a*) See Art. **16.**
(*b*) See Art. **19.**

(5) See Fig. 18 (*b*).

(6) (*a*) See Art. **13.**
(*b*) See Art. **15.**

(7) See Art. **8.**

(8) (*a*) See Art. **5.**
(*b*) See Art. **3.**
(*c*) See Art. **4.**
(*d*) See Art. **3.**

(9) See Art. **78.**

(10) See Art. **3.**

(11) See Art. **50.**

(12) (*a*) See Art. **72.**
(*b*) See Figs. 43 and 44.

(13) See Fig. 16 and Art. **18.**

(14) See Art. **2.**

(15) See Art. **18.**

(16) See Art. **38.**

(17) See Art. **47.**

(18) See Art. **16.**

(19) See Art. **34.**

(20) See Art. **1.**

CARPENTRY

(PART 4)

(1) See Art. **51**.
(2) See Art. **13.**
(3) See Art. **14.**
(4) See Art. **25.**
(5) See Art. **32.**
(6) See Art. **54.**
(7) See Art. **46.**
(8) See Art. **35.**
(9) See Art. **40.**
(10) See Art. **44.**
(11) See Art. **47.**
(12) See Art. **19.**
(13) See Art. **21.**
(14) See Art. **26.**
(15) See Art. **32.**
(16) See Art. **1.**
(17) See Art. **8.**
(18) See Fig. 40 (*a*).
(19) See Art. **8**.
(20) See Art. **11**.

ROOFING

(1) See Table I.

(2) See Art. **18.**

(3) See Arts. **110, 111,** and Fig. 55.

(4) See Arts. **32, 50, 56,** and **62.**

(5) See Art. **92.**

(6) See Arts. **17** and **49.**

(7) See Arts. **8** to **10.**

(8) See Arts. **48** to **50** and **56.**

(9) (*a*) See Art. **113** and Fig. 57.
(*b*) See Arts. **94, 95** and Fig. 47.

(10) See Art. **133** and Figs. 65 and 66.

(11) See Arts. **143, 144,** and **146.**

(12) See Arts. **74** and **75.**

(13) See Arts. **25** to **29.**

(14) See Art. **18** and Fig. 8.

(15) See Art. **151** and Fig. 81.

(16) (*a*) See Art. **31** and Fig. 12.
(*b*) See Art. **116** and Fig. 60.

(17) See Table VI.

(18) (*a*) See Arts. **35** to **37** and Figs. 15 to 17.
(*b*) See Art. **51** and Fig. 26.
(*c*) See Art. **67** and Figs. 31 and 32.

(19) See Arts. **105, 114,** and Fig. 58.

(20) See Art. **41** and Fig. 19.

INDEX

NOTE.—All items in this Index refer first to the section and then to the page of the section. Thus *Abutments, §25, p3*, means that *Abutments* will be found on page 3 of section 25. When there are several items having the same key word, this is, for brevity, omitted after the first reference, and the other items are indented, or set in, from the left margin, to indicate this omission, which never consists of more than one word. Thus, under the key word *Asbestos* is found the indented item, *roofing, Laying*; this is read *Laying asbestos roofing*, the capitalization of *Laying* denoting the first word of the reference.

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